

3D Telepresence for Medical Consultation

Extending Medical Expertise Throughout, Between and Beyond Hospitals



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1. *The University of North Carolina at Chapel Hill*
2. *Göteborg University and The University College of Borås*

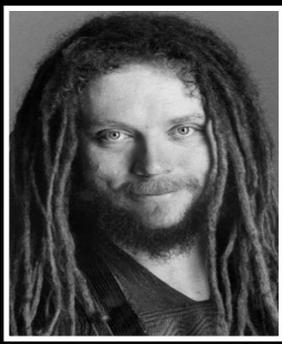


Outline

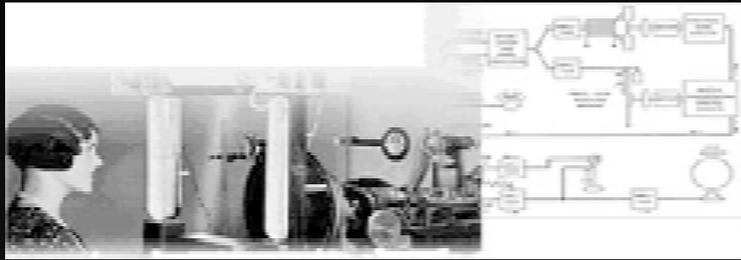
- General history
- UNC history
- NIH-NLM 3D Medical Consultation project
 - 3D Telepresence System (Graphics & Vision Research)
 - Networking Research
 - Evaluation
- Conclusions

Presence and Telepresence

- Presence
 - Experience of one's **physical** environment (Gibson, 1979)
 - Sense of **being** in an environment (Steuer, 1992)
 - Human **reaction** to **immersion** (Slater, 2003)
- Telepresence
 - Experience of presence...by means of a **communication medium** (Steuer, 1992)
 - **Temporally** or **spatially** distant “real” environment



2D Video Conferencing (from Jaron Lanier)

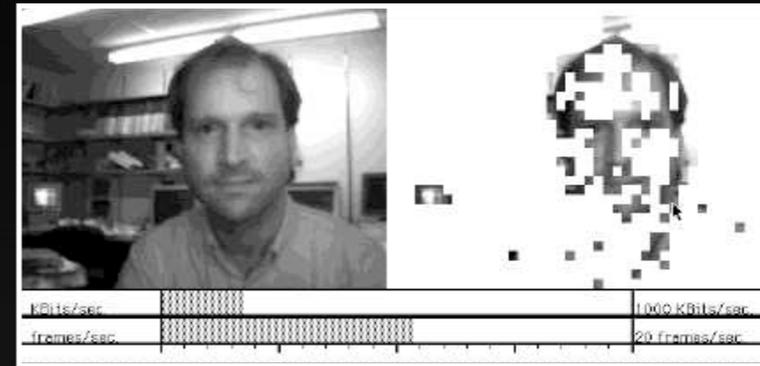


This image quality was described as "perfect" by the New York Times reporter who covered the first demo.

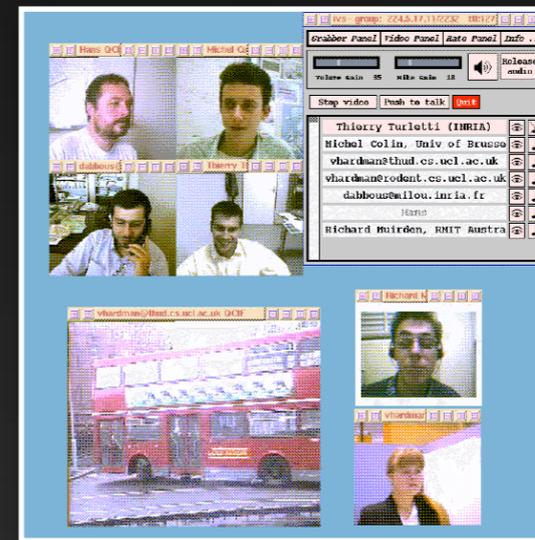
1927



1964



CUSEEME: Tim Dorsey, first image



INRIA
1992

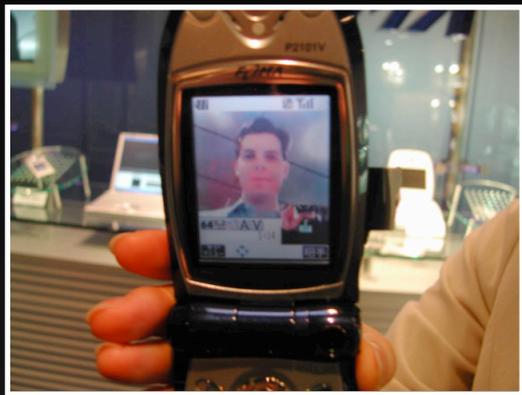


NetMeeting
Now



Implied 3D Perspectives

DoCoMo phone



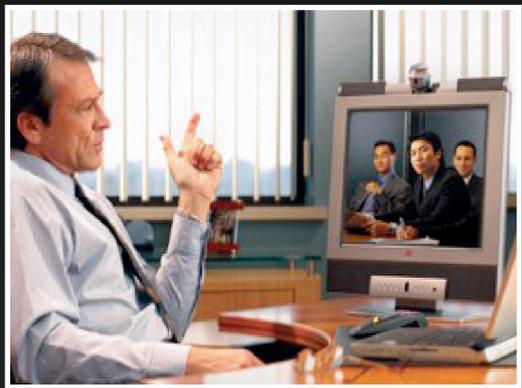
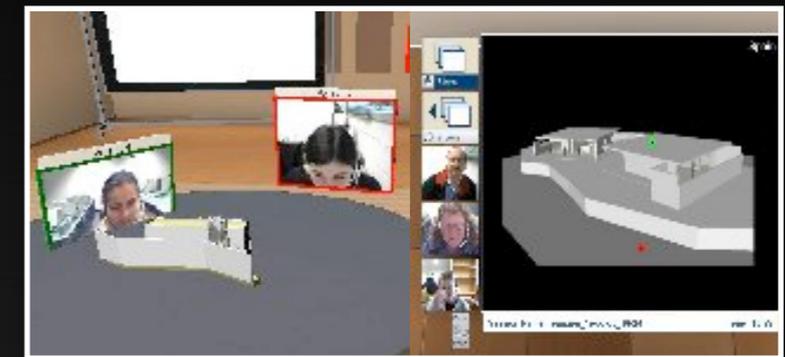
TeleSuite



Apple iChat



Video Videos in Space
(Hills et al., ICAT 2005)



Polycom



Typical campus
setup



Barco



“HYDRA”, Bill Buxton’s 1980’s
approach to the >2 users
problem

Why 3D Telepresence?

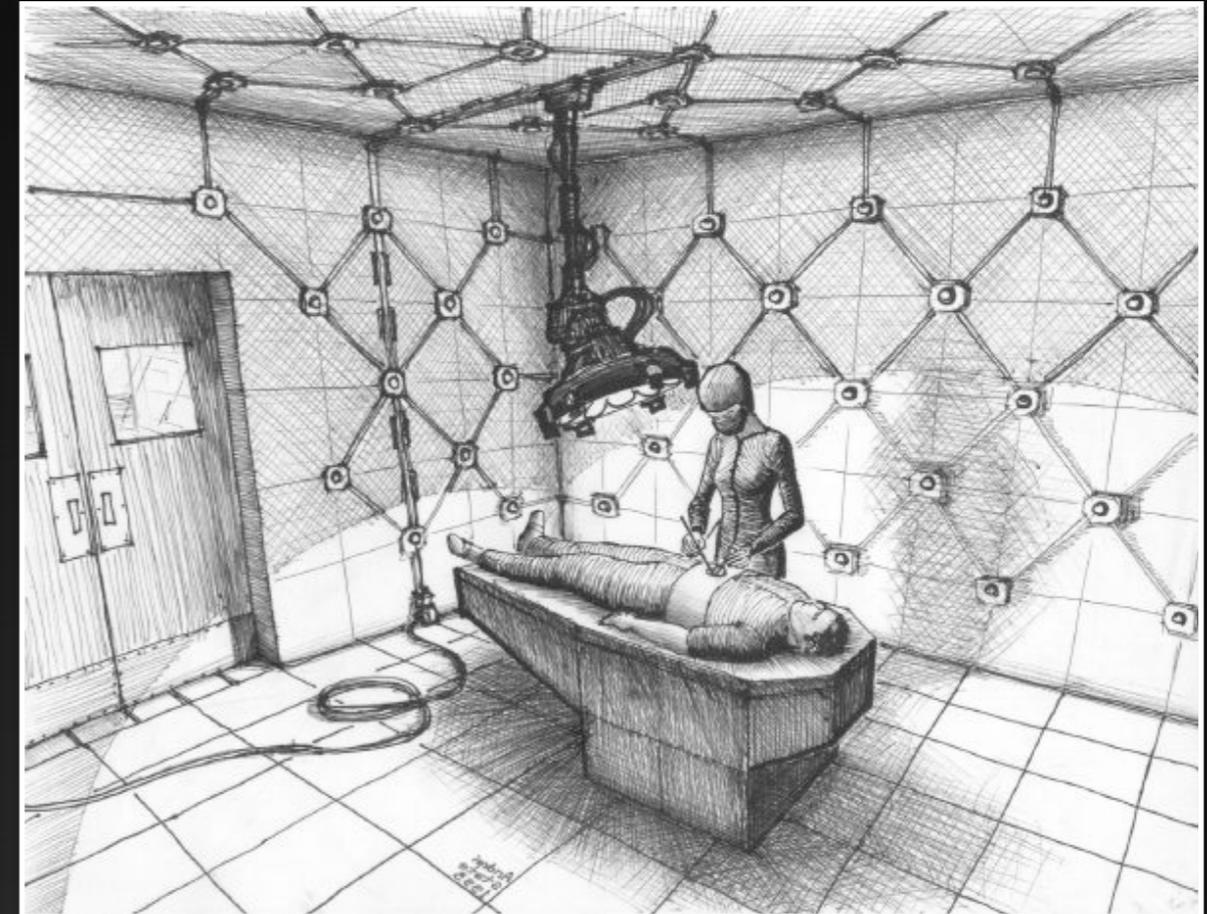
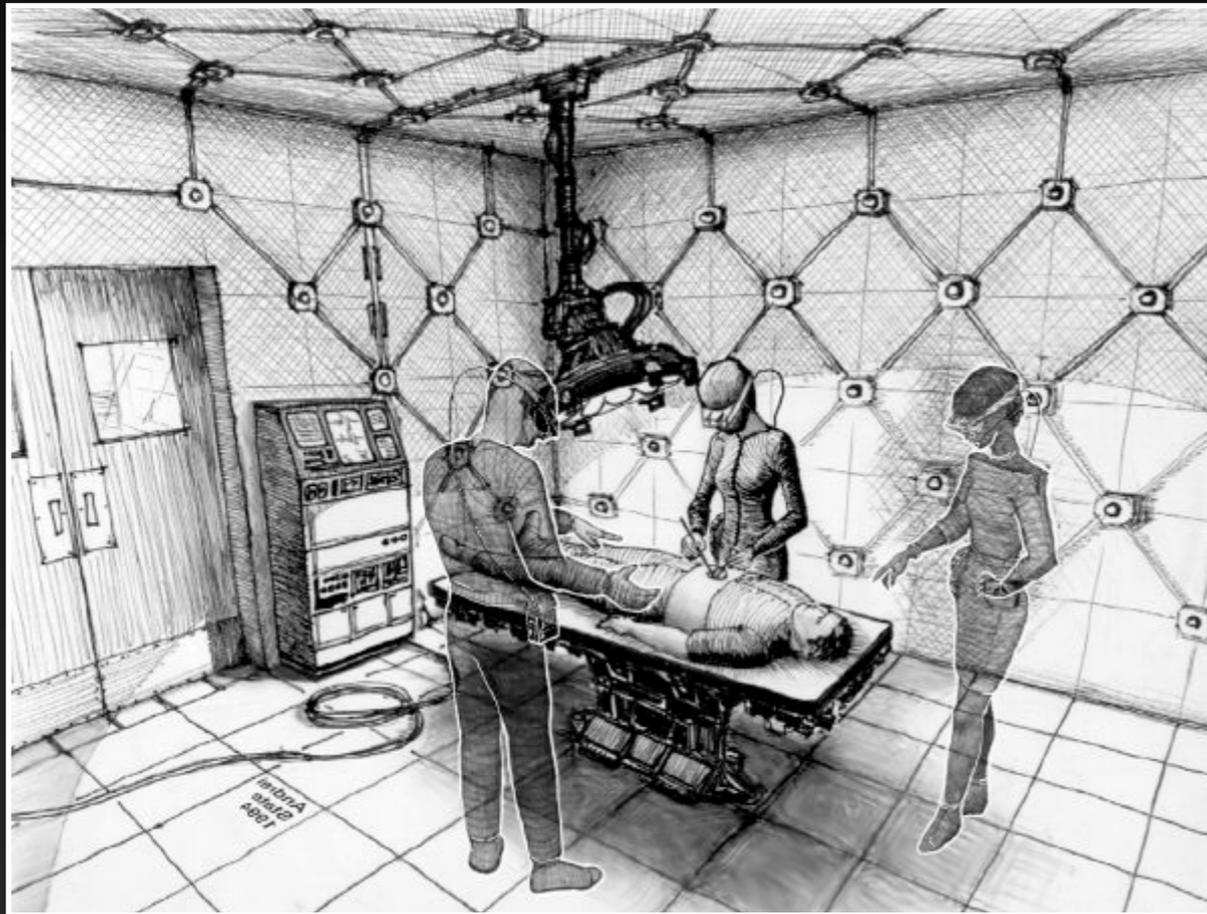
- Important visual cues
 - Natural **viewpoint control** (Kienzle, 2000)
 - **Depth perception** (Ellis et al., 2001)
- Presence!
 - **Internal vs. external** factors (Slater & Usoh, 1993)
 - Mel Slater's "Break in presence" (Usoh et al., 1999)



*University of Texas Medical Branch at
Galveston's Telehealth Center*

“Sea of Cameras” (1994)

H. Fuchs, G. Bishop, K. Arthur, L. McMillan, R. Bajcsy, S. Lee, H. Farid, and T. Kanade.
Virtual space teleconferencing using a sea of cameras. In Proceedings of the 1st International Symposium on Medical Robotics and Computer Assisted Surgery, Pittsburgh, PA, 1994.



Andrei State, 1994

Recent *telepresence*-related projects

- 1998-2000 National Tele-immersion Initiative: Advanced Network & Services, UNC, Penn, Brown,..
- 2001-2005 NSF: Real-Time Long-Distance Terascale Computation for Full Bandwidth Tele-Immersion (UNC, Penn, Pittsburgh Supercomputing Ctr.)
- 2001-2005 NSF: Electronic Books for the Tele-Immersion Age: A New Paradigm for Teaching Surgical Procedures (Brown , UNC)
- 2002-2006 DOE-Sandia: Group Teleconferencing
- 2003-2007 NIH: 3D Telepresence for Medical Consultation

1998-2000 National Tele-immersion Initiative: Advanced Network & Services, UNC, Penn, Brown,..



3D Telepresence (2003)

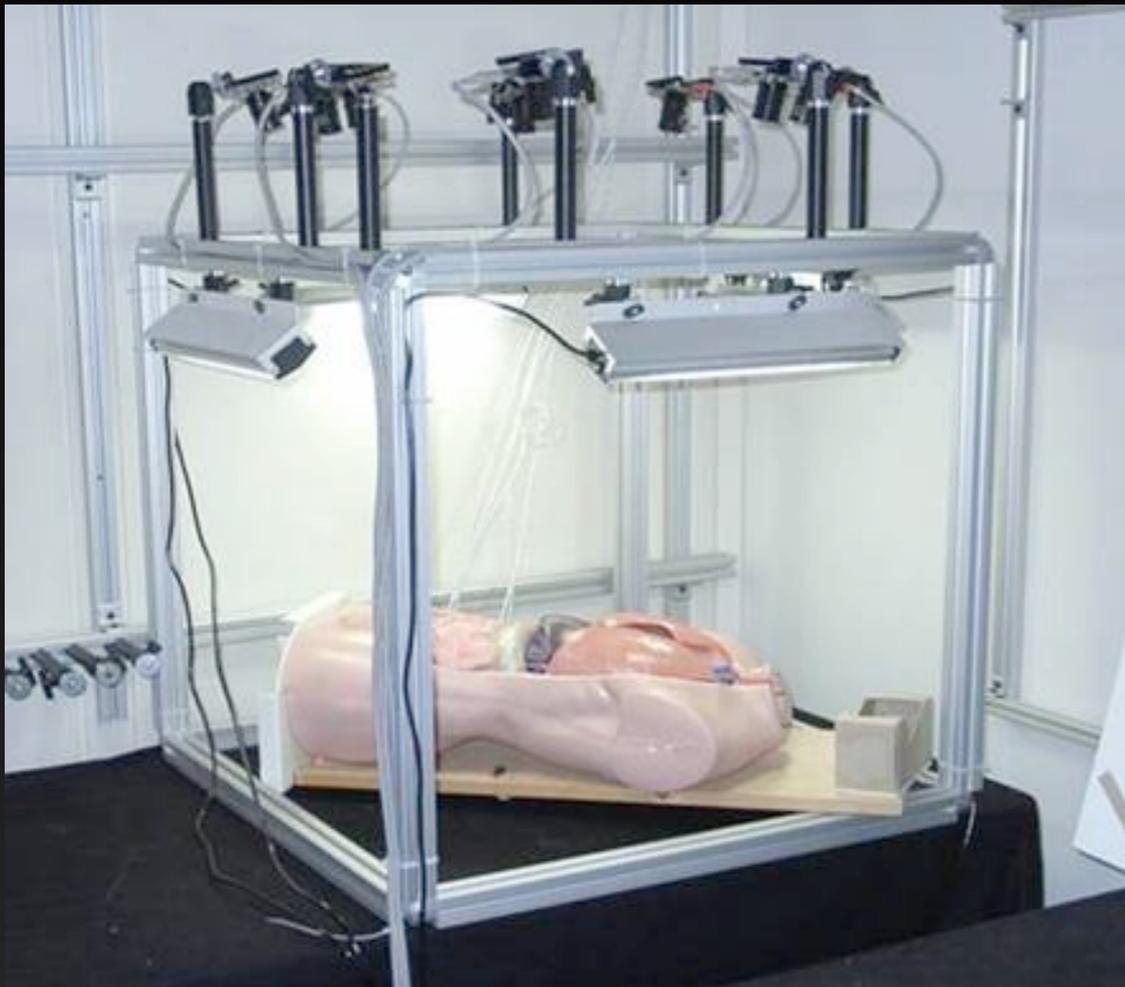


University of North Carolina at Chapel Hill (Fuchs, Towles, Welch et al.)

2001-2005 NSF: Real-Time Long-Distance Terascale Computation for Full Bandwidth Tele-Immersion (UNC, Penn, Pittsburgh Supercomputing Ctr.)



2001-2005 NSF: Electronic Books for the Tele-Immersion Age: A New Paradigm for Teaching Surgical Procedures (Brown, UNC)



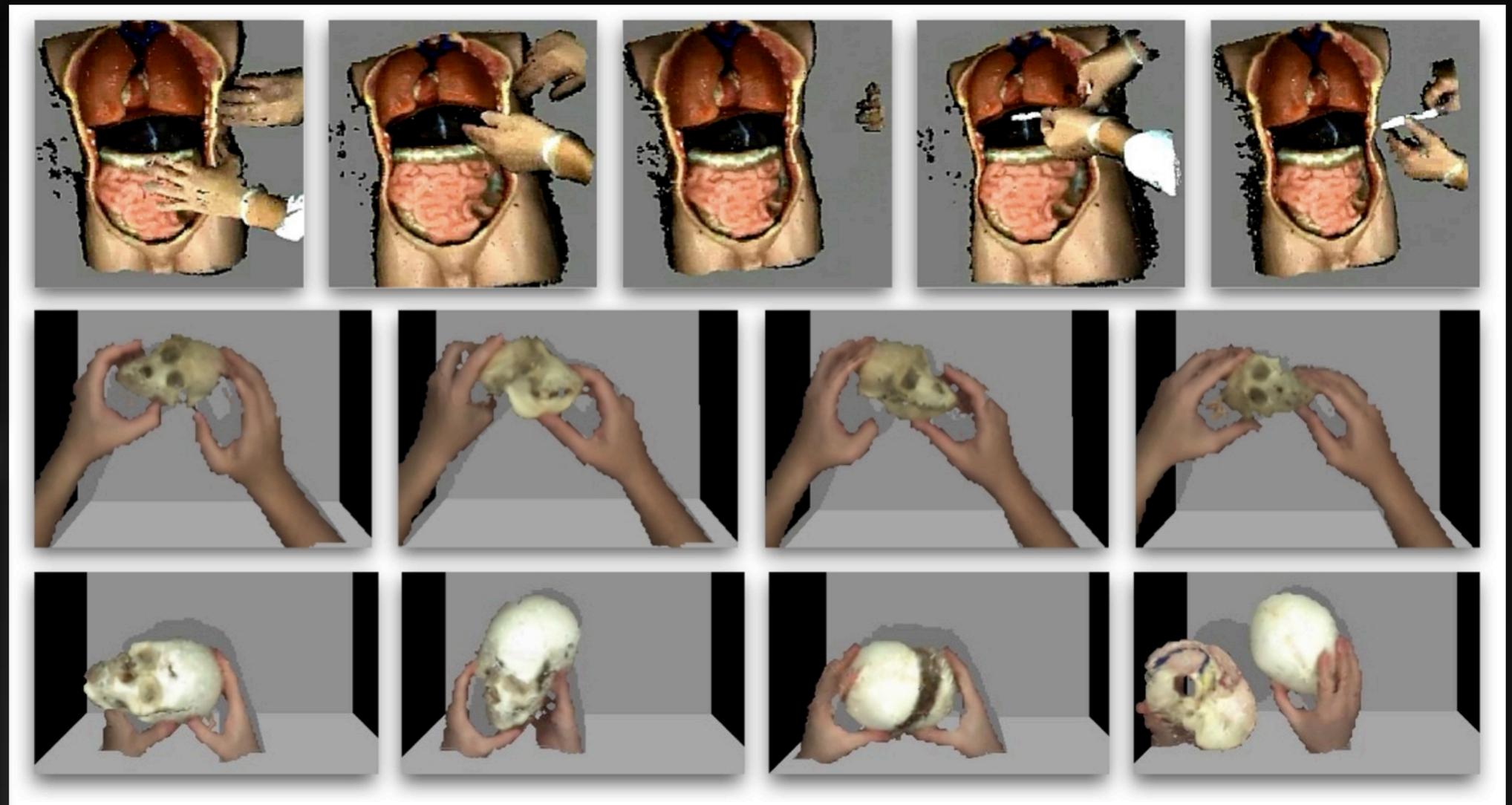
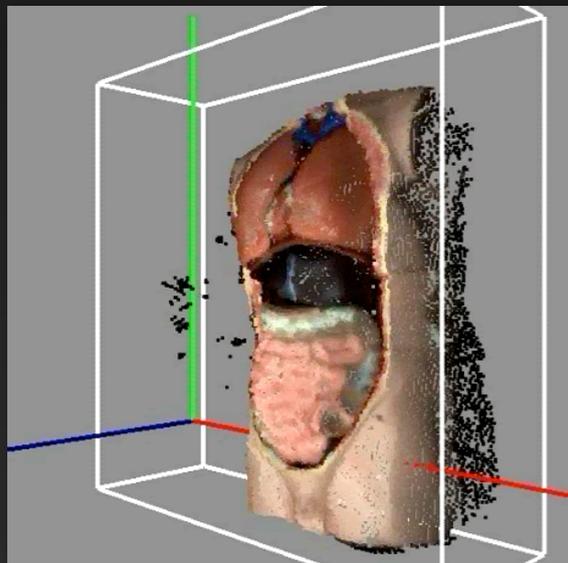
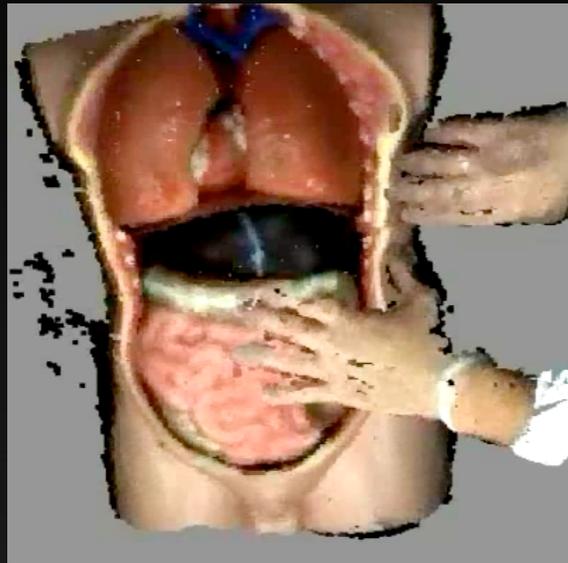
The camera cube
(8 cameras)



Mock exploratory
laparotomy procedure
(Dr. Bruce Cairns)

Reconstruct Dynamic 3D

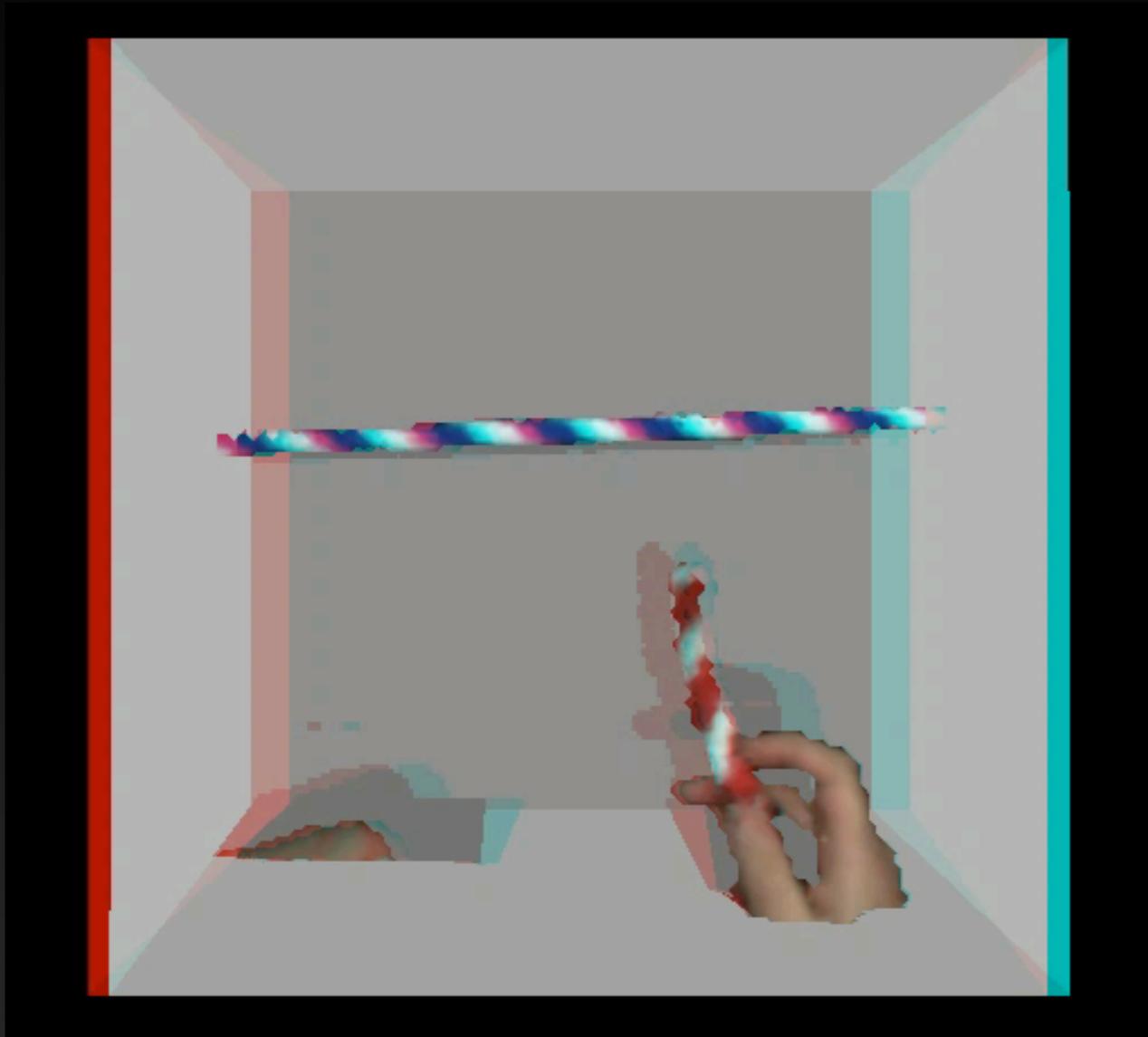
View-Dependent Pixel Coloring (R. Yang)



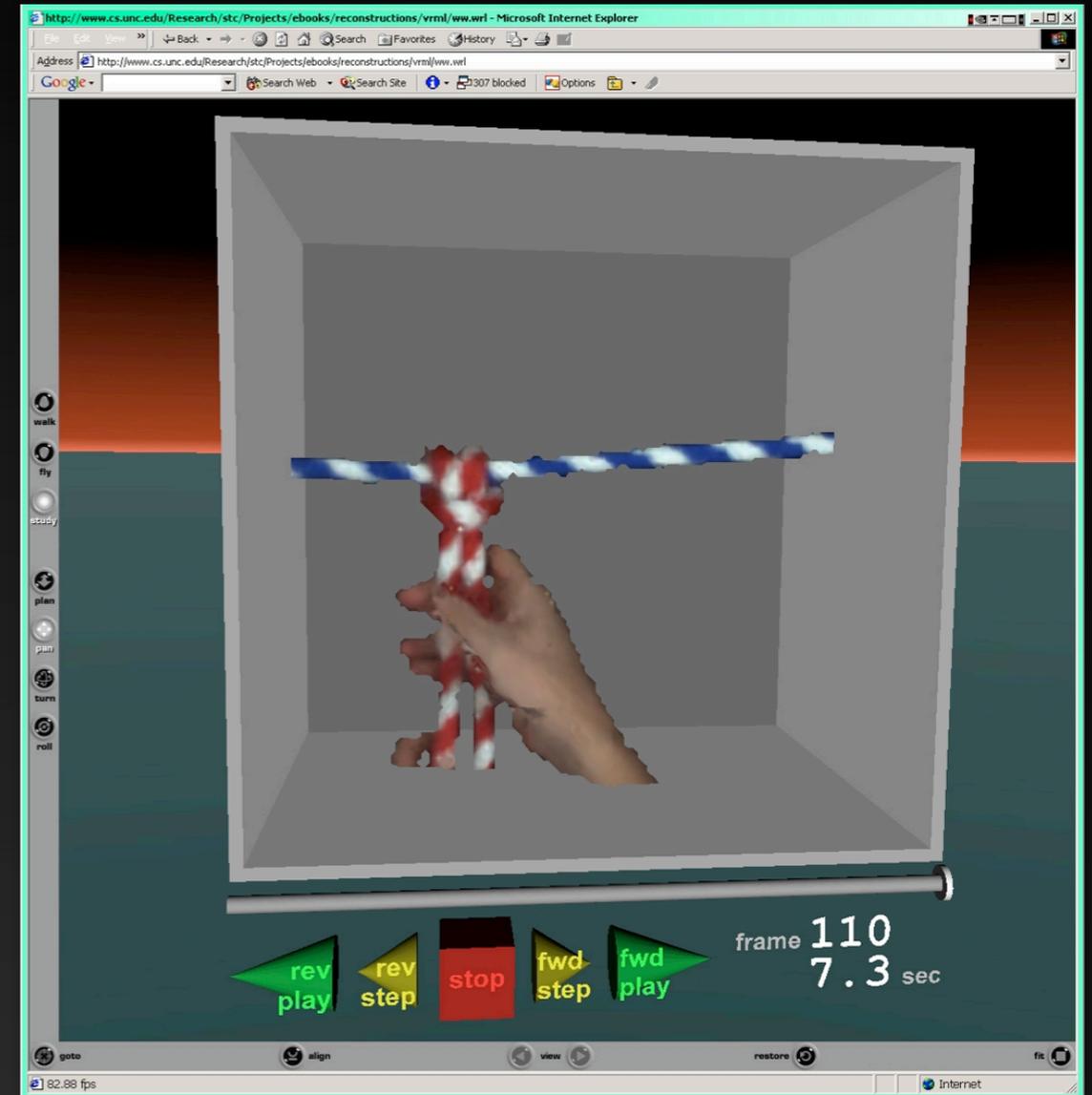
With M. Pollefeys, A. Ilie, and A. State

Knot Tying (Suturing)

Anaglyphic Stereo Movie



Dynamic VRML (Screenshot)



(google: unc ebooks reconstructions)

2002-2006 DOE-Sandia: Group Teleconferencing

Concept

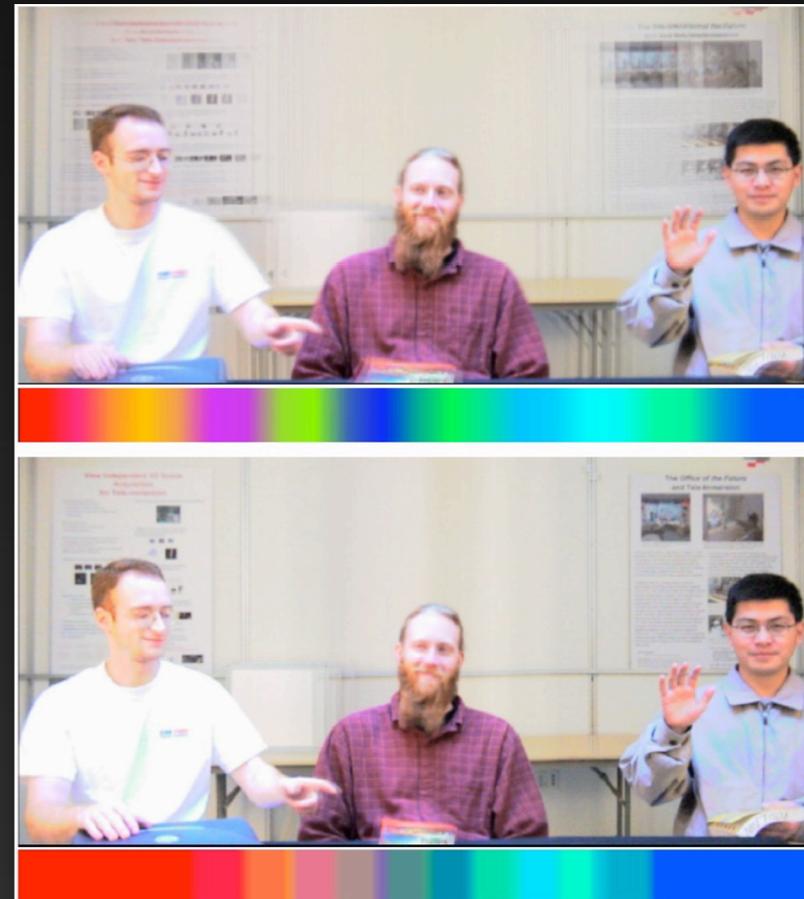
Local



Remote

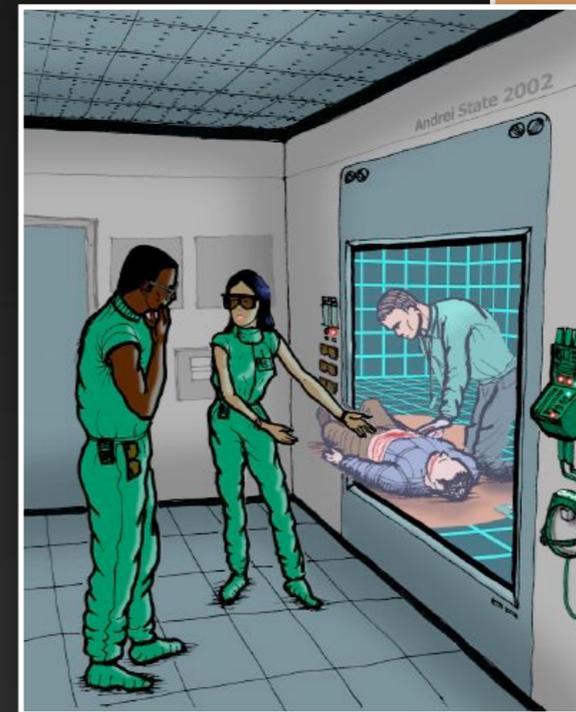


Prototype



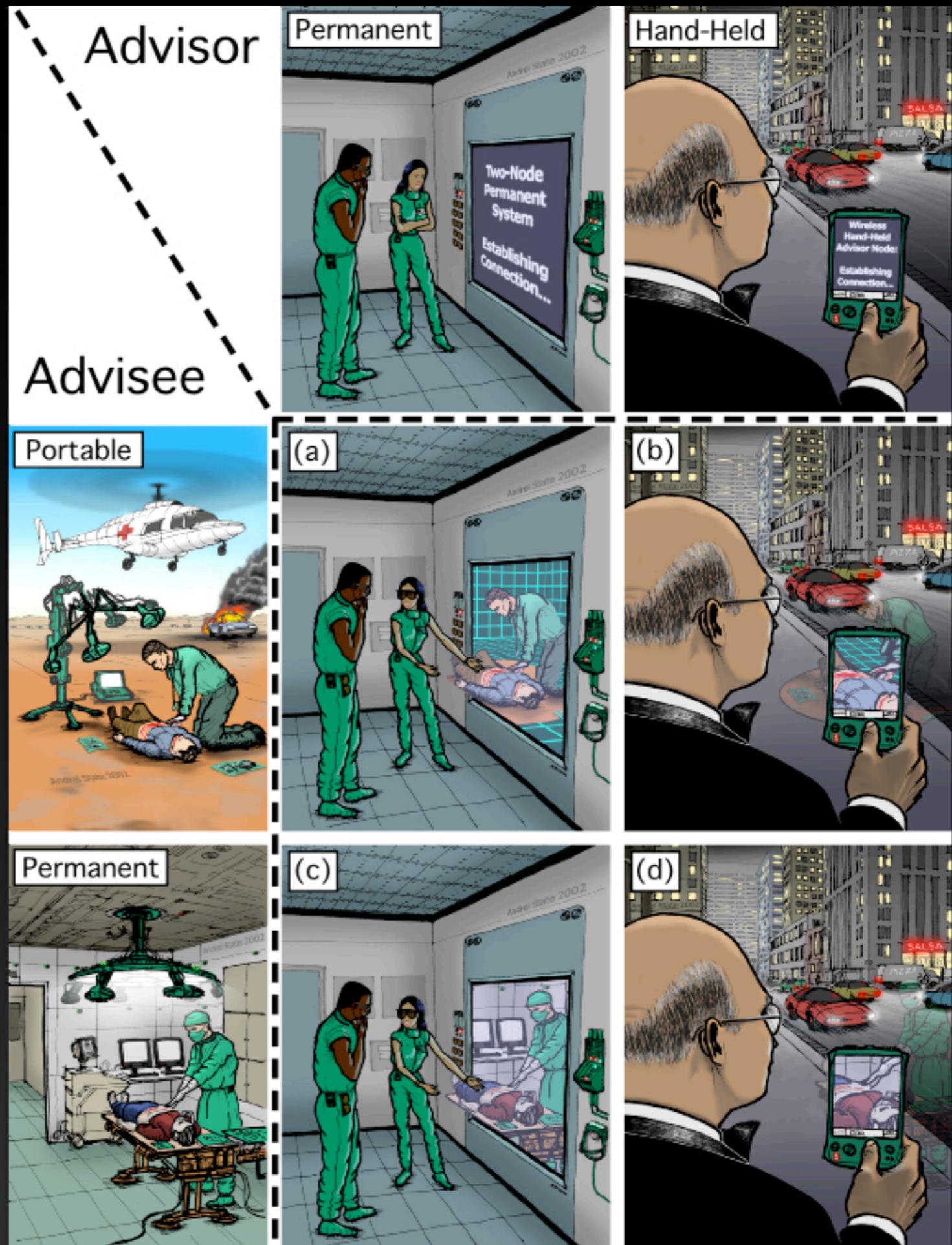
3D Medical Consultation (Live 3DTP Over Distance)

- Trauma is “the hidden epidemic of modern society” (Coats & Goode, 2001)
- Trauma management ideal application of telemedicine (Smith, 2001)
- Viewpoint control and depth perception continue to limit telemedicine acceptance (Tachakra et al., 1996, 2000, 2001; Taylor, 1998)”
- Difficult airway management (cricothyrotomy)



Research

- On-line “live” reconstruction and/or novel view synthesis
- Tracking (head, PDA)
- Displays
- Network congestion and variability adaptation
- Evaluation



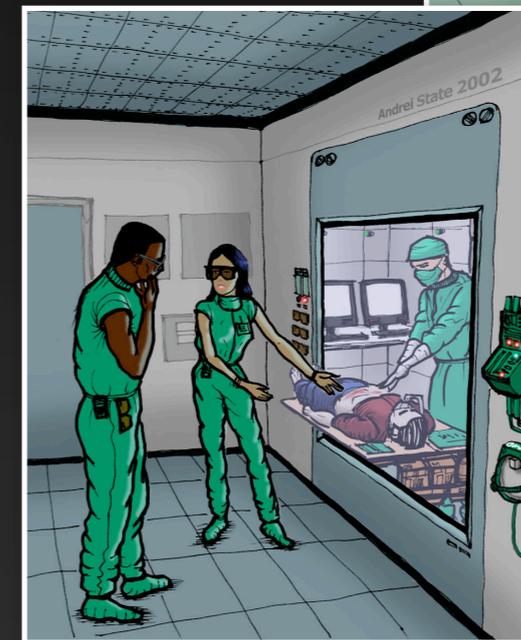
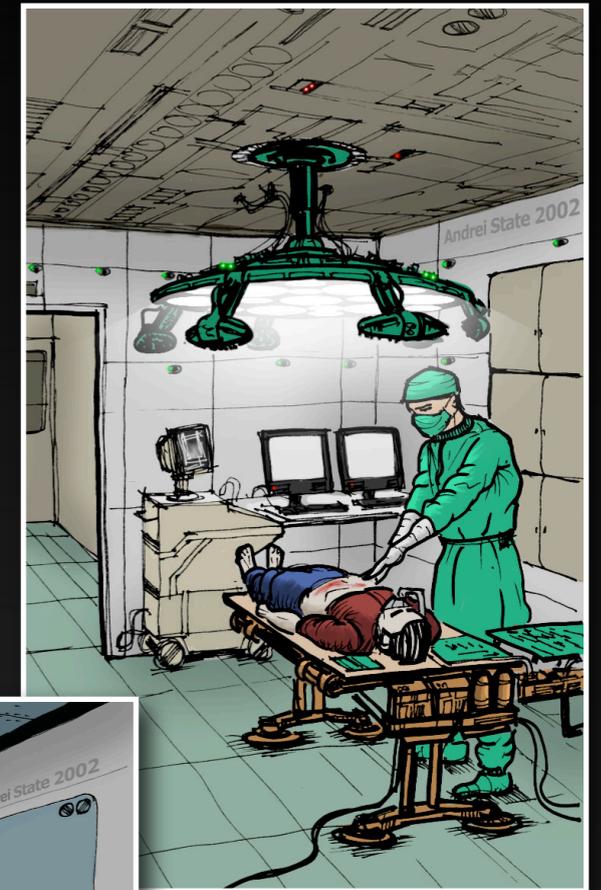
Andrei State, UNC, 2003

3D Telepresence System

Interactive Computer Vision+Graphics



Hospital-Based Acquisition System: First Prototype



- Two pan-tilt-zoom cameras on roll-away stand
- UNC Jaycee Burn Center ICU
- Recorded multiple surgeries



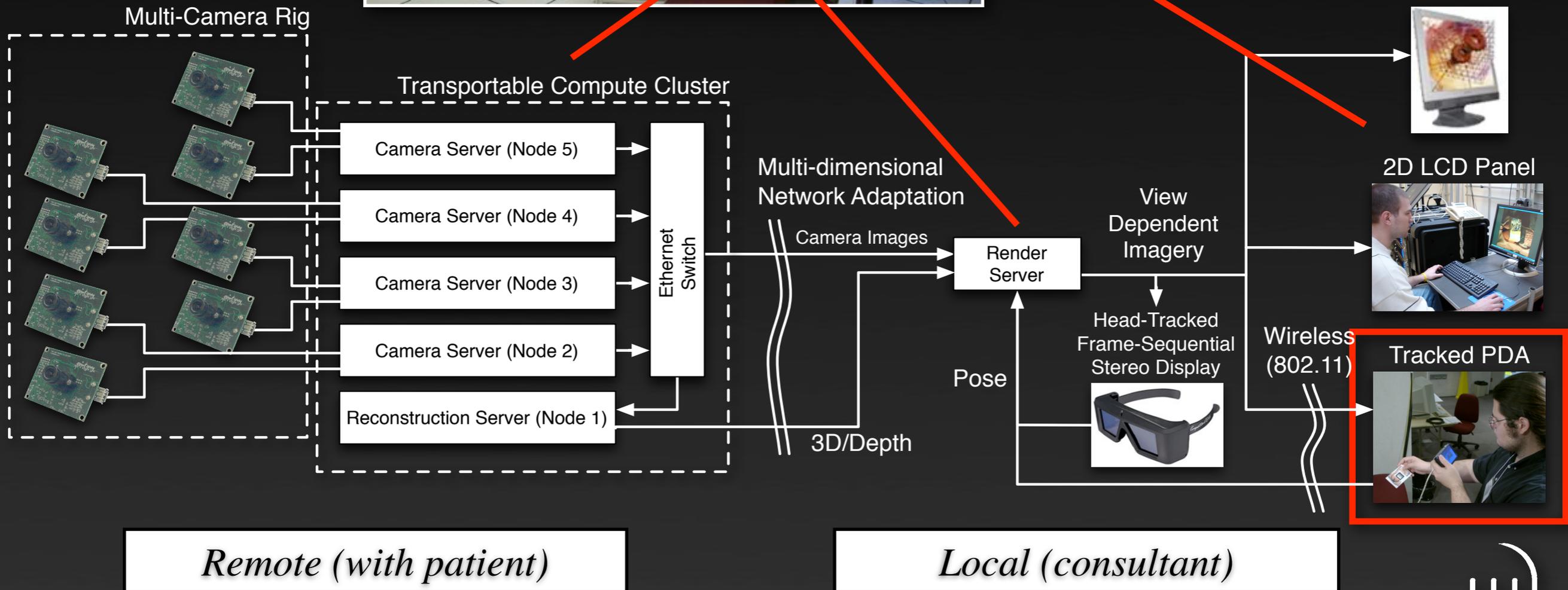
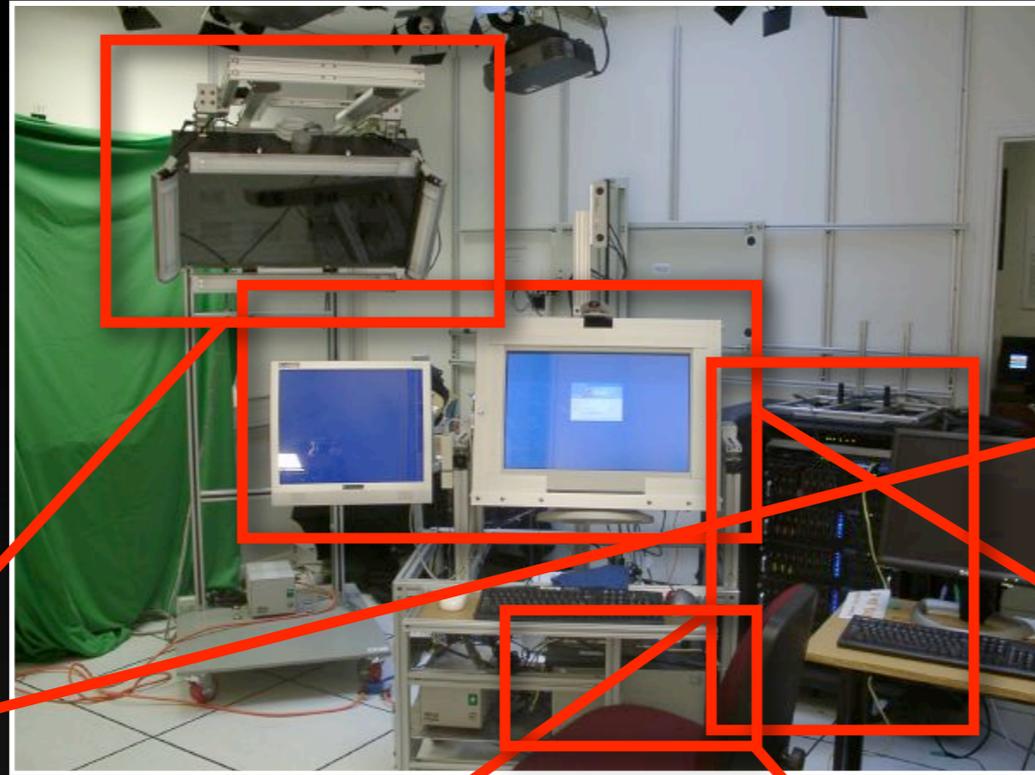
Hospital-Based Acquisition System: First Prototype



Recorded Tracheostomies

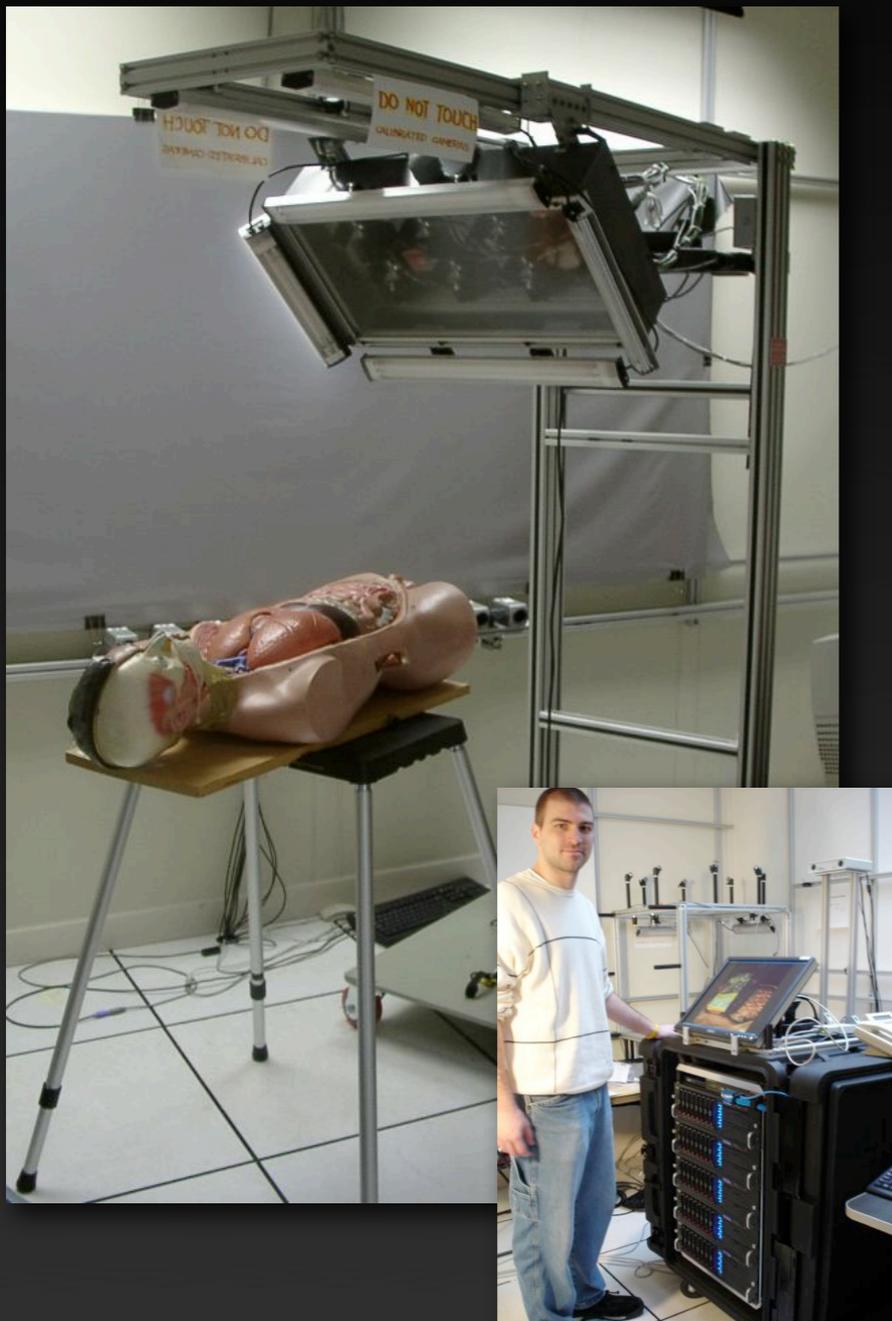


3DMC System



Portable Capture/Reconstruction

3D Reconstruction on Graphics Hardware

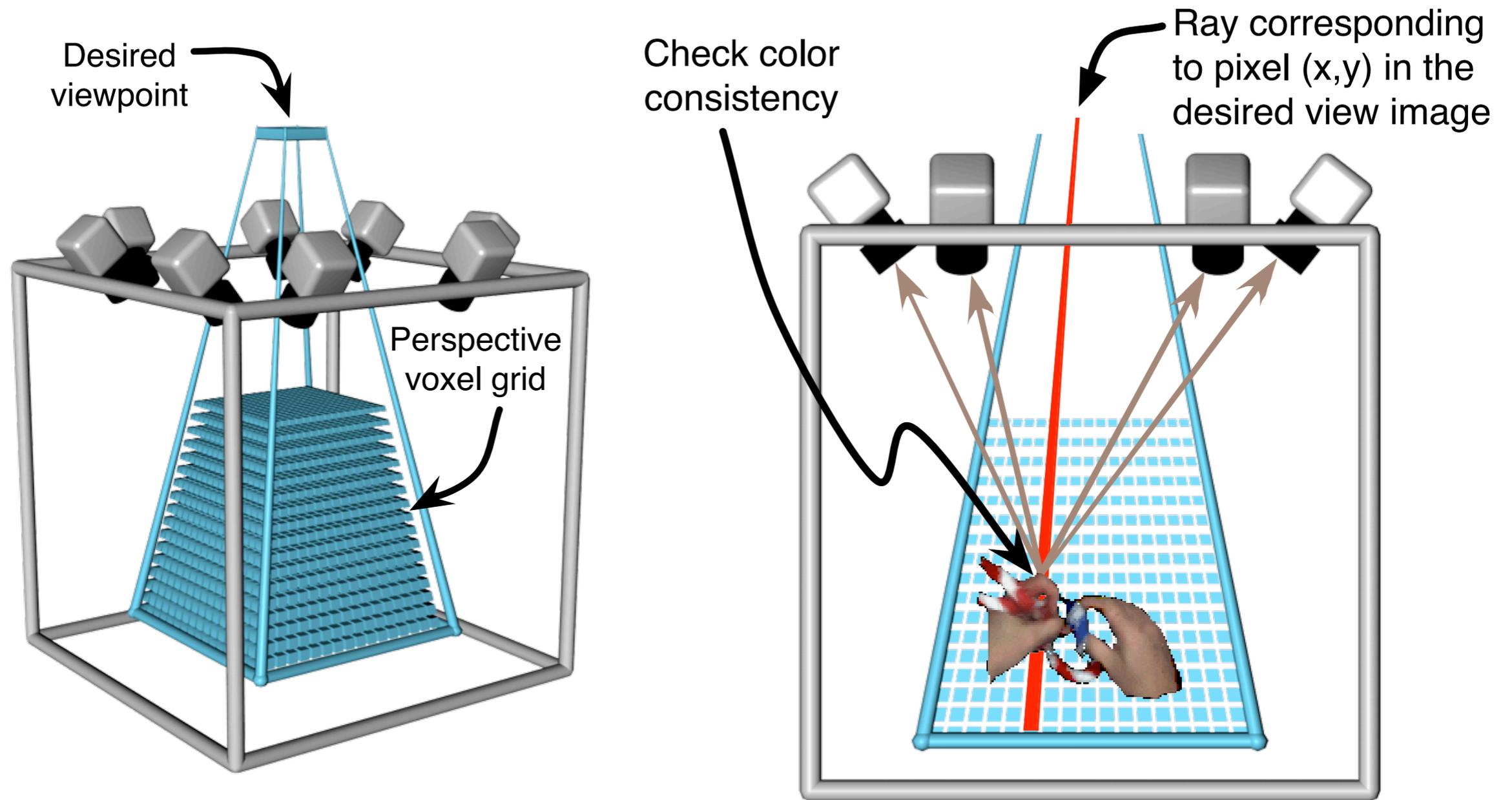


With R. Yang, M. Pollefeys, A. State,
H. Yang, and A. Ilie

Ben Jacobs Live

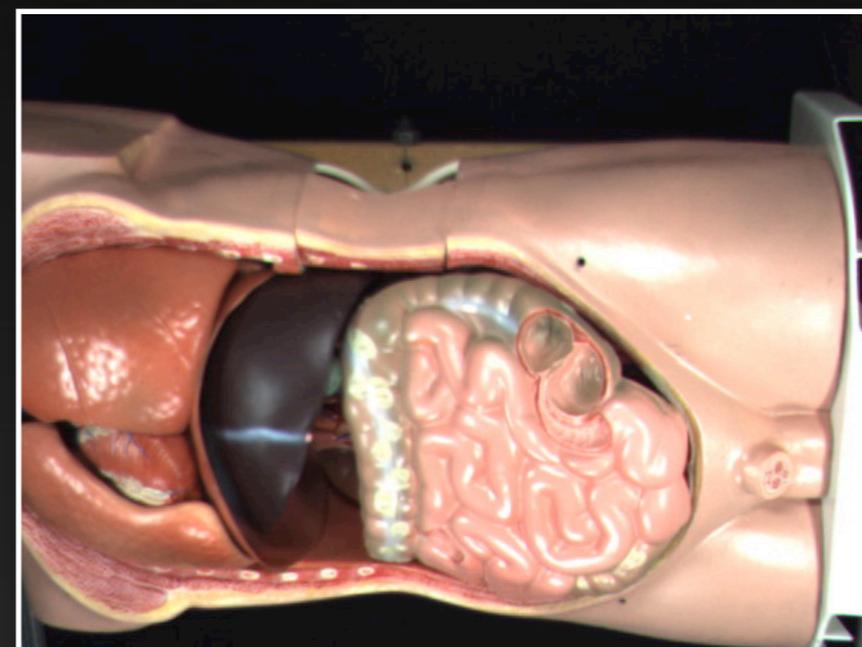
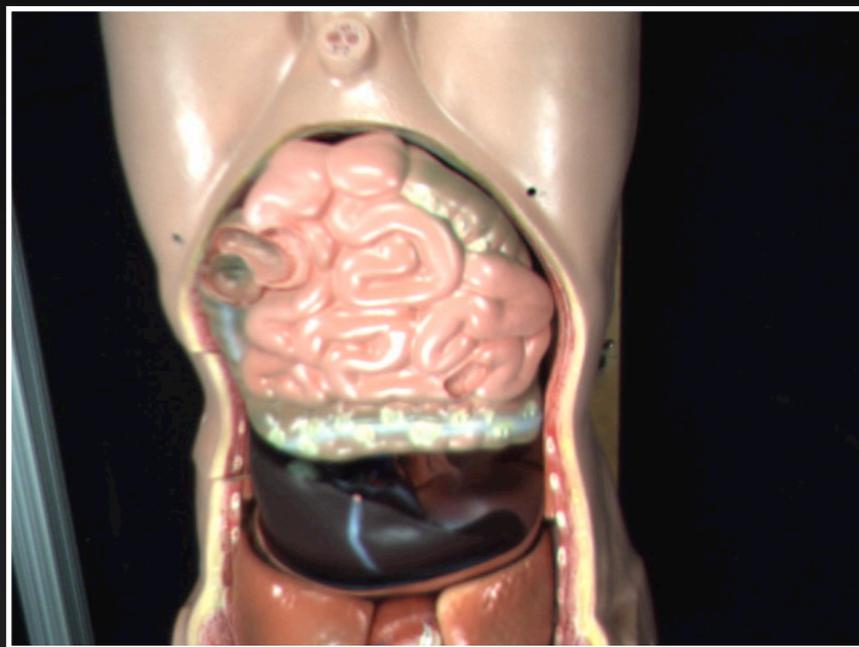


View-Dependent Pixel Coloring (VDPC)



Common Difficulties—VDPC Handles

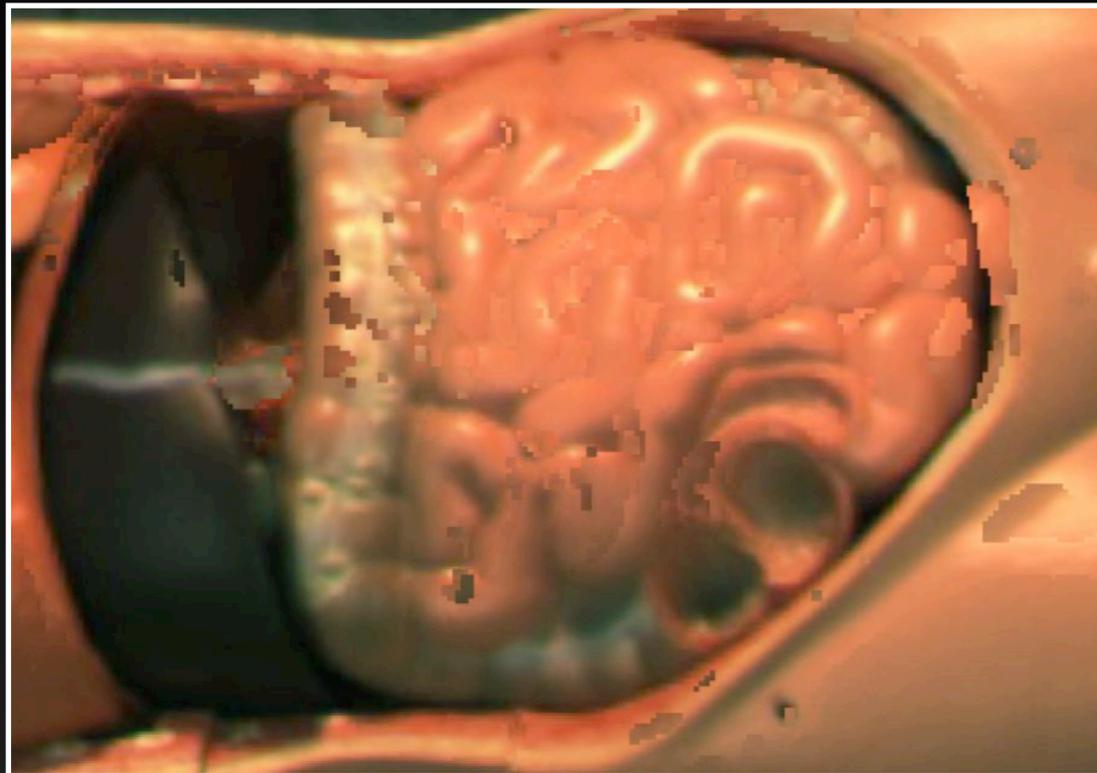
- Shiny surfaces—false negatives
- Textureless surfaces—ambiguity



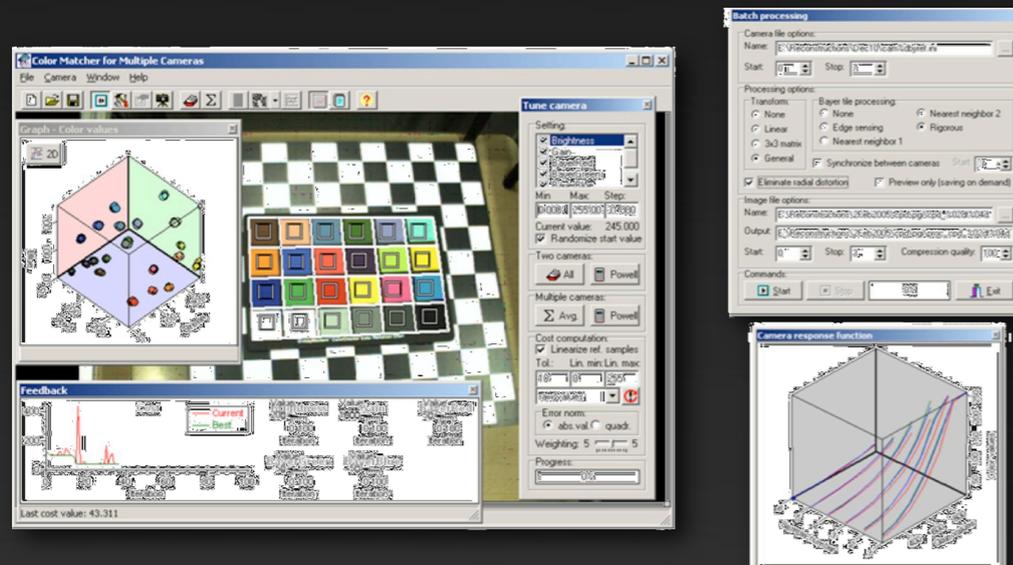
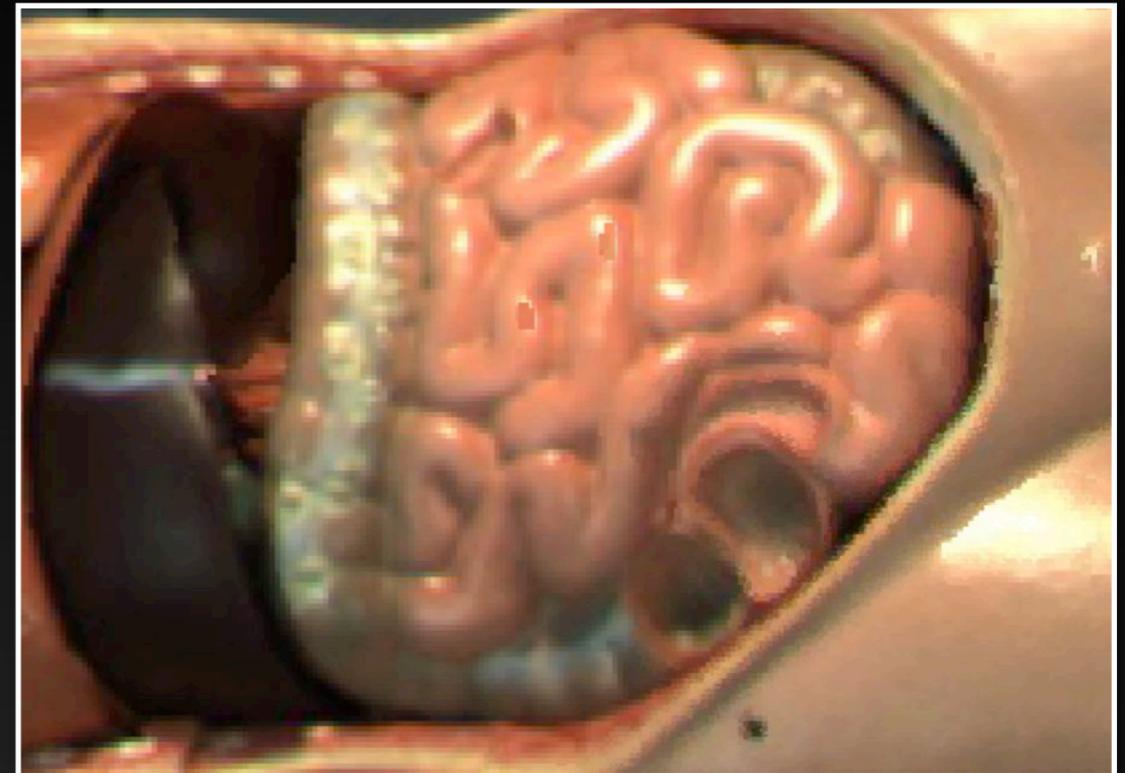
[..., IJIG 2004, ICCV 2003, Pacific Graphics 2002]

Color Matching

Before



After

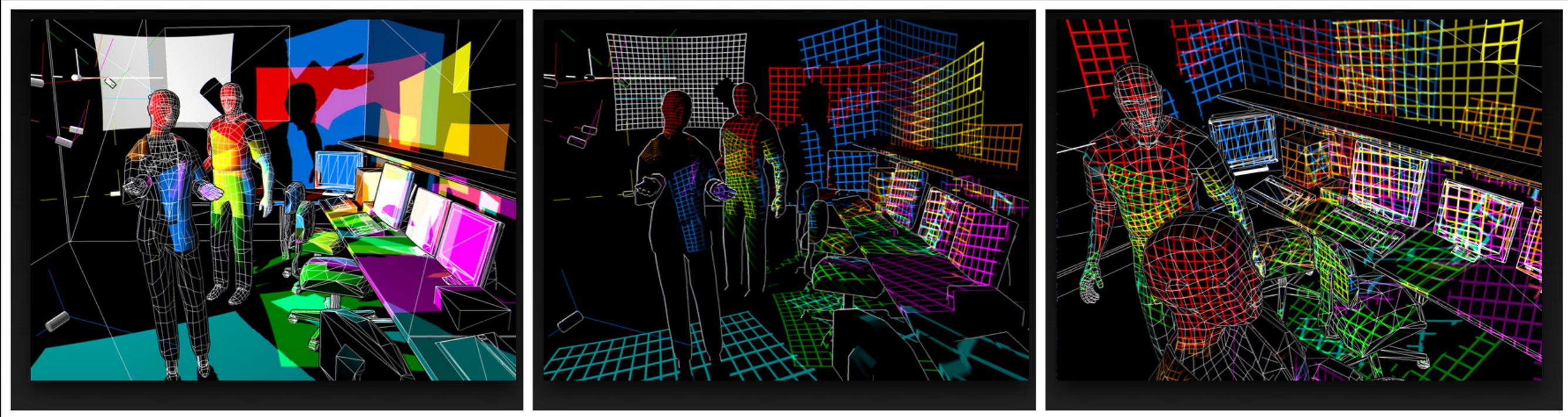


ICCV 2005, with Adrian Ilie
(tool available for download)



Camera Placement

OpenGL-based simulator (geometry only)

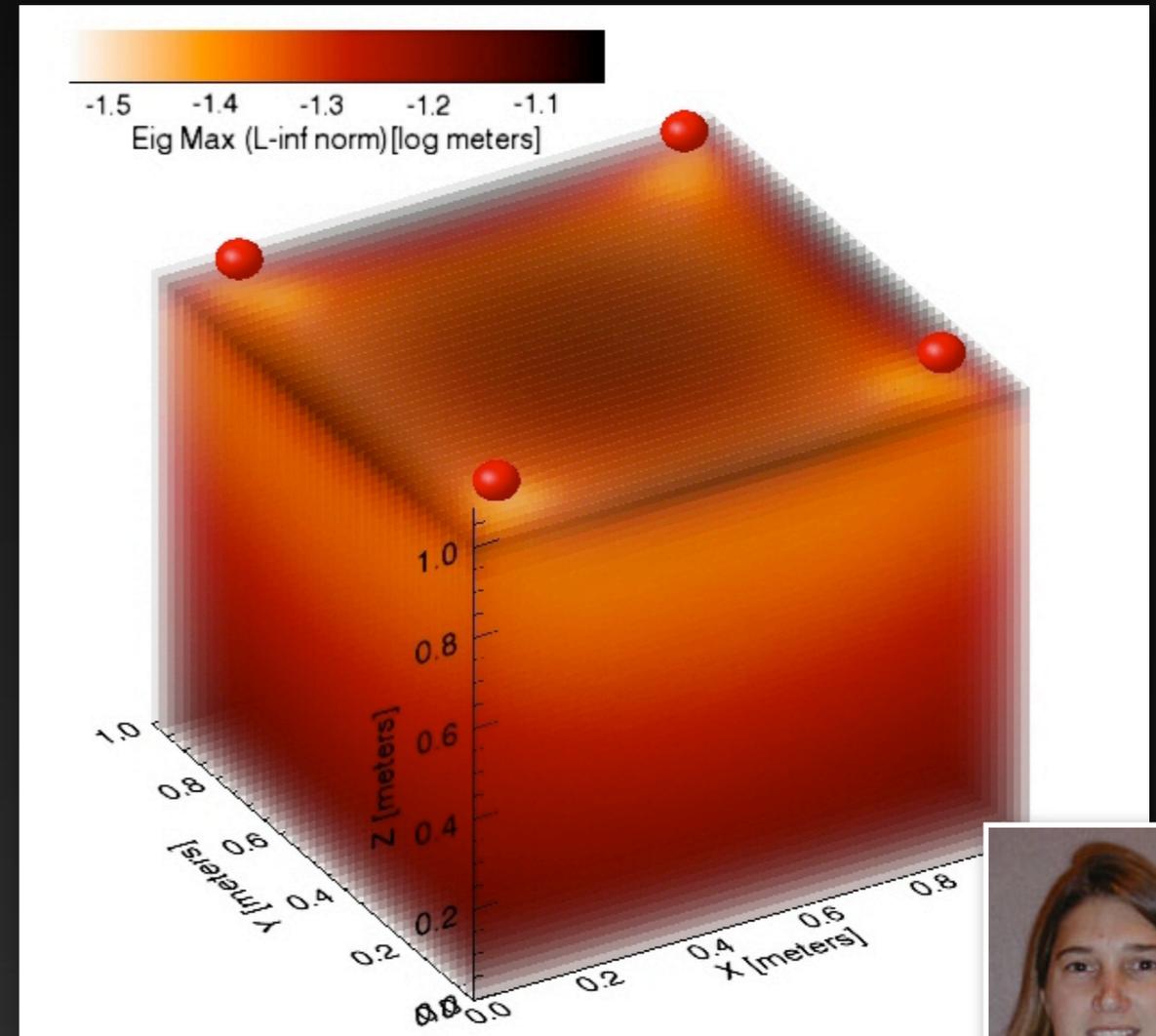
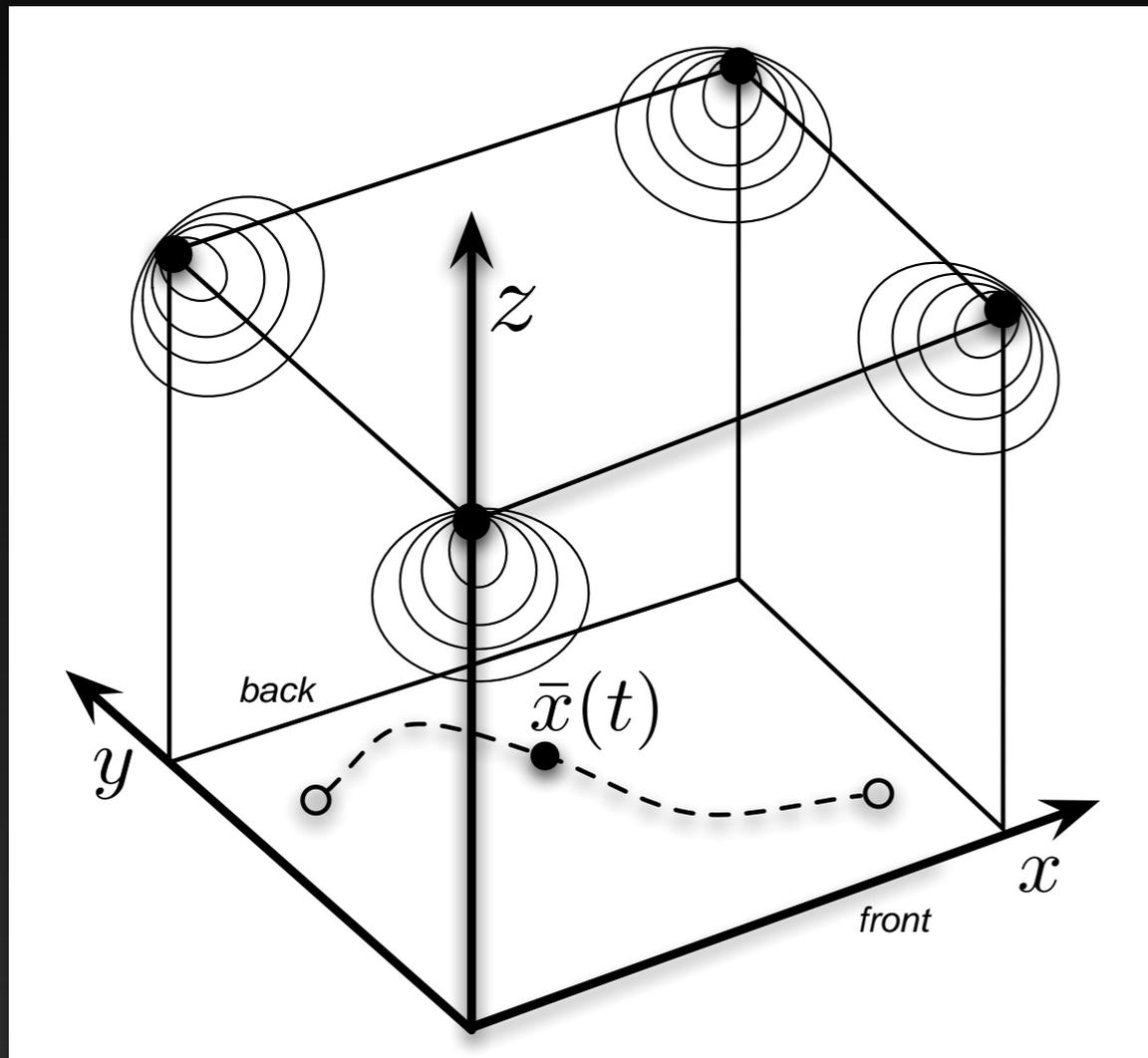


SPIE Engineering Reality of Virtual Reality 2006, with Andrei State



Optimal Sensor Placement (Steady-State Error Covariance)

$$P_{\infty} = \lim_{t \rightarrow \infty} \mathbf{E} \left\{ (\bar{x}(t) - \tilde{x}(t)) (\bar{x}(t) - \tilde{x}(t))^T \right\}$$



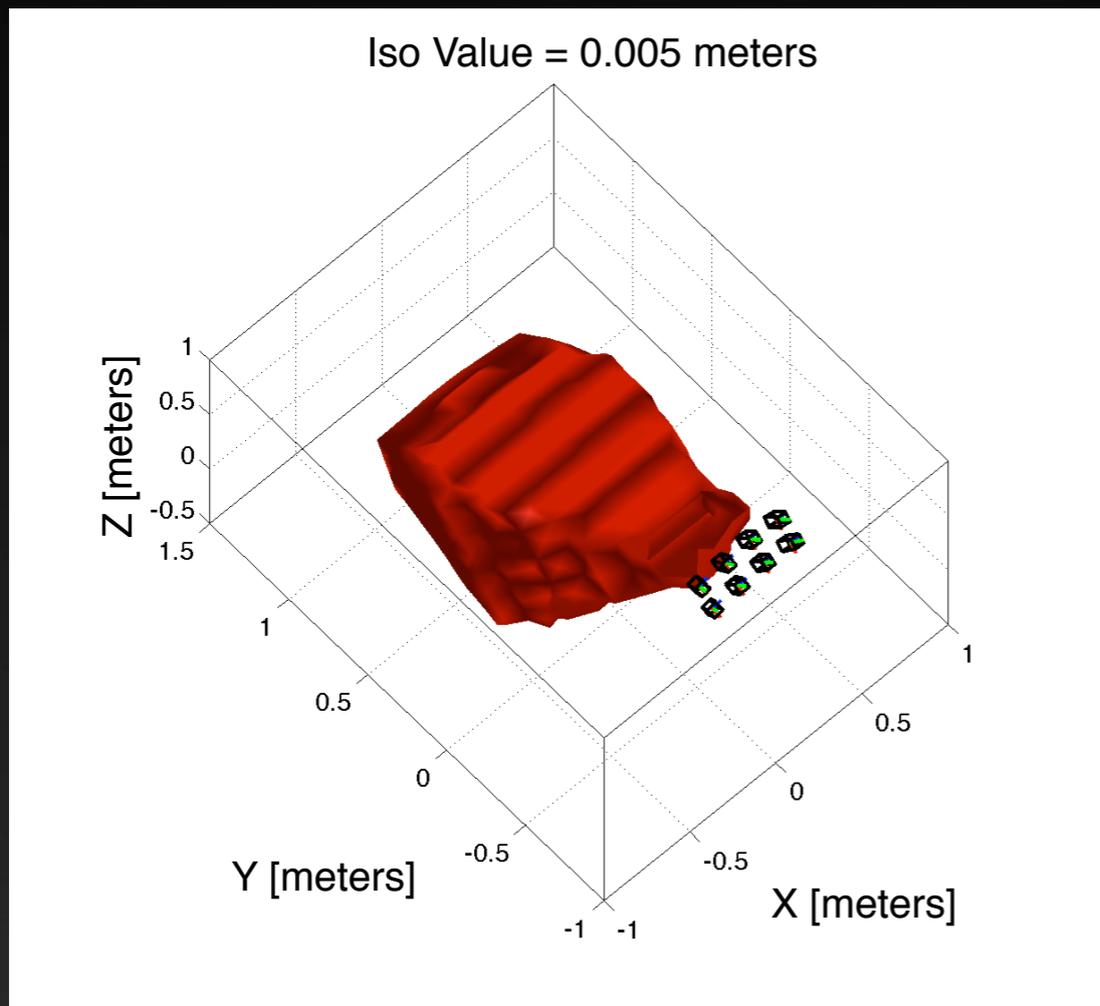
VRST 2005, with Danette Allen



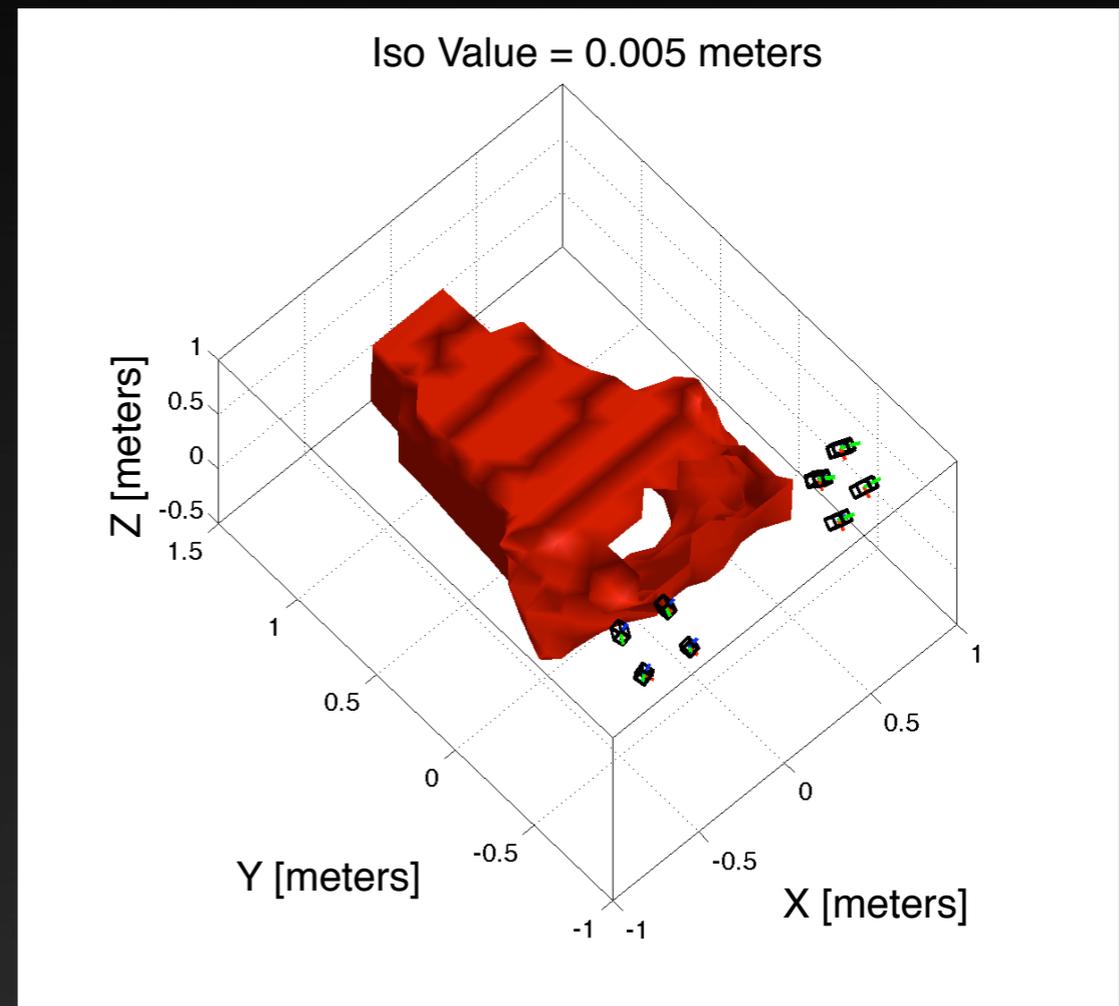


3DMC Camera Configuration

8 Original Cameras

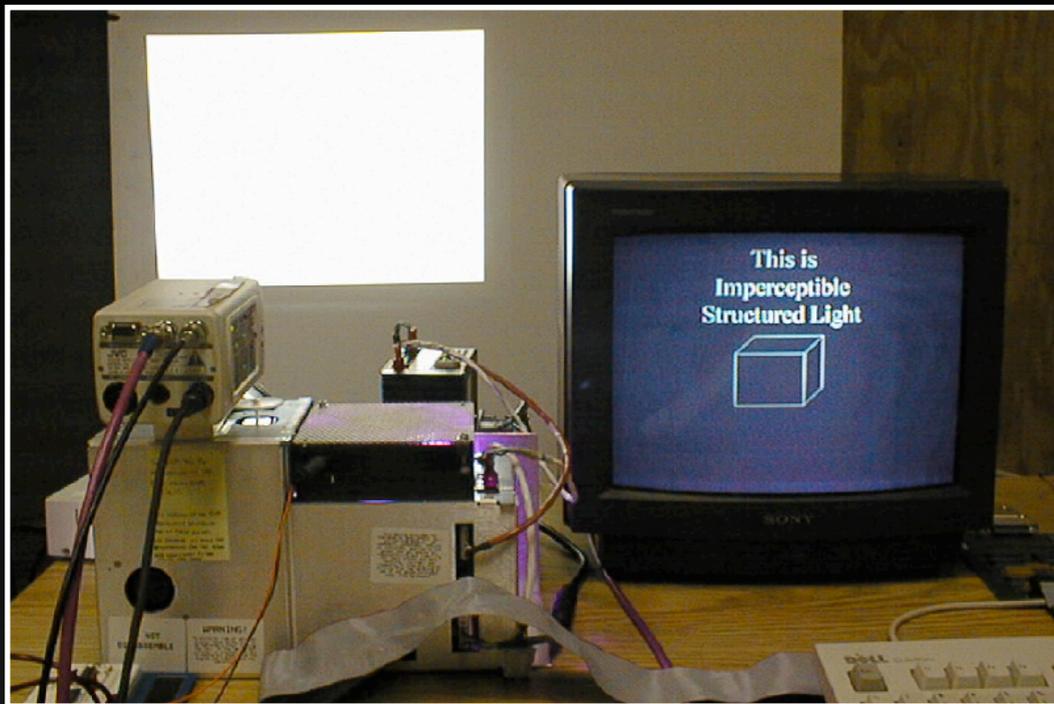


Spread Apart

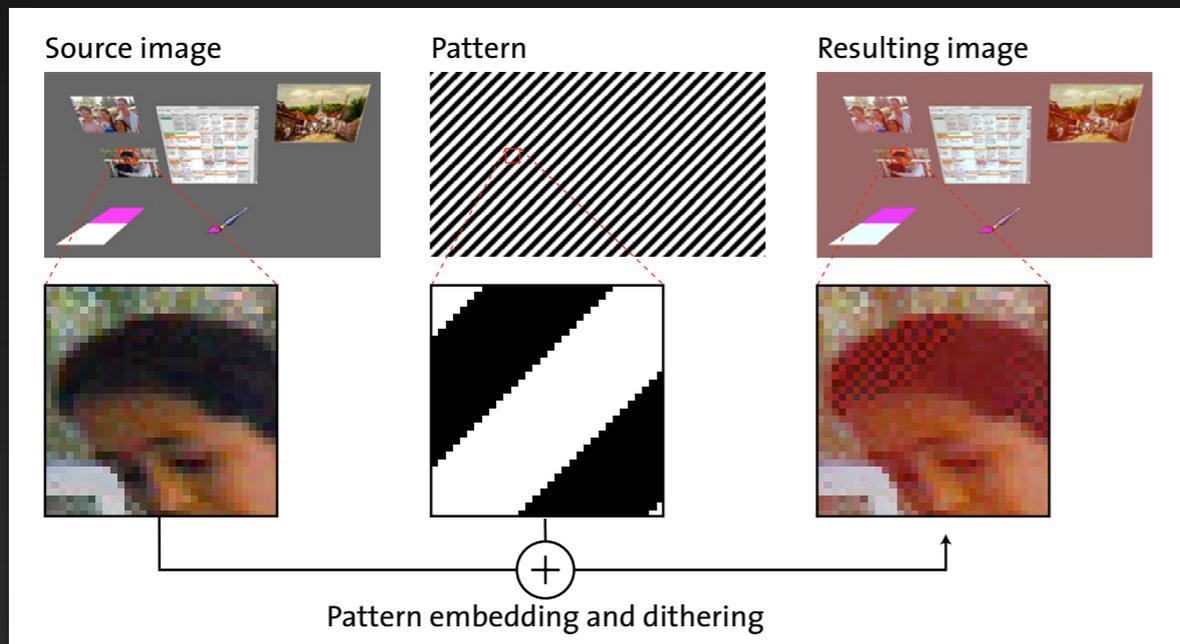


With Adrian Ilia and Marc Macenko

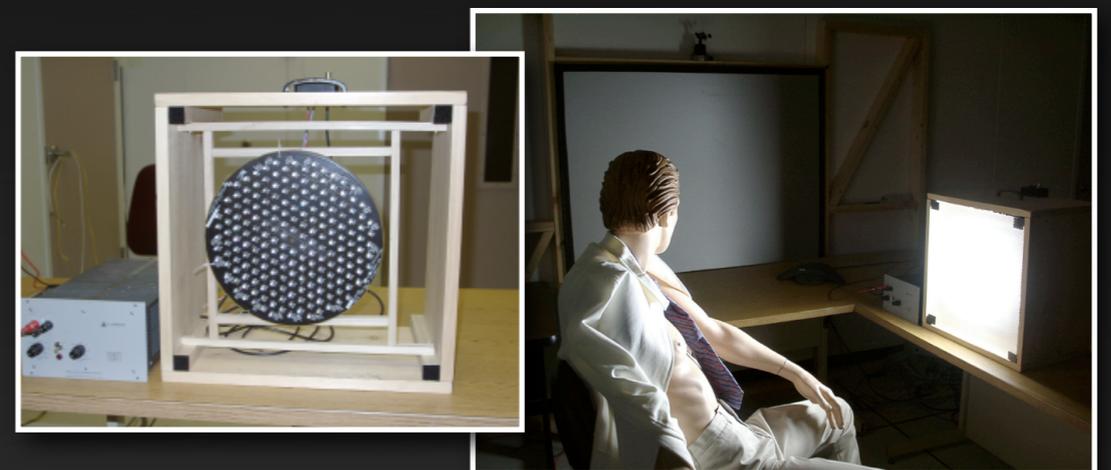
Imperceptible and Digital Light



Raskar, Welch et al., SIGGRAPH 1998



Cotting et al., ISMAR 2004



UNC Chapel Hill, 2004

3DMC with a PDA

- Extend expertise beyond the hospital
- Cell phone today—voice only
- Quick *visual* consultation (in advance of heading in)
 - View-dependent imagery
 - Natural interface—a “magic lens”
 - Fitzmaurice, CACM 93
 - Fitzmaurice and Buxton, CHI 94
 - Paskan and Woodward, ISMAR 03
 - Mohring, Lessig, and Bimber, ISMAR 04
- Series of paradigms & prototypes



Absolute One-Handed Paradigm

- HiBall-3000™ Optical Tracking System
- Toshiba e800 PDA
- Difficulty “finding” and “keeping” the patient in view (while moving PDA)



Bruce Cairns, M.D.

(Director of Research, Jaycee Burn Center, UNC-Chapel Hill)

Relative One-Handed Paradigm

- Put the patient (surrogate) on a table near by
- Better at finding the patient
- Still difficult to keep the patient in view



The Conversion of Dr. Cairns



“I don’t want to use two hands.”

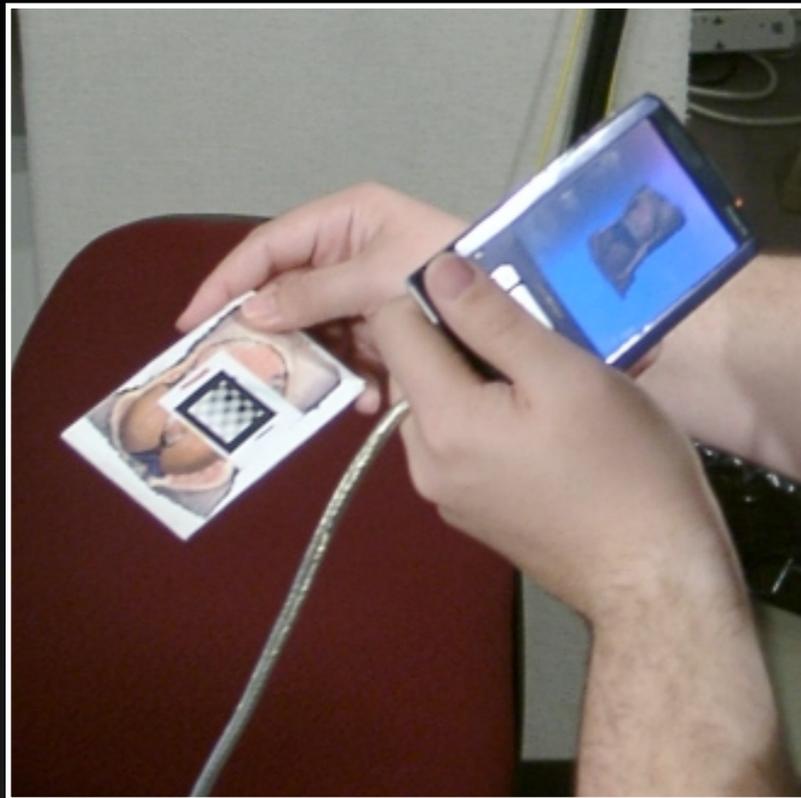
“This isn’t so bad.”

“Cool—I can flip the patient over.”

“This is really nice!”

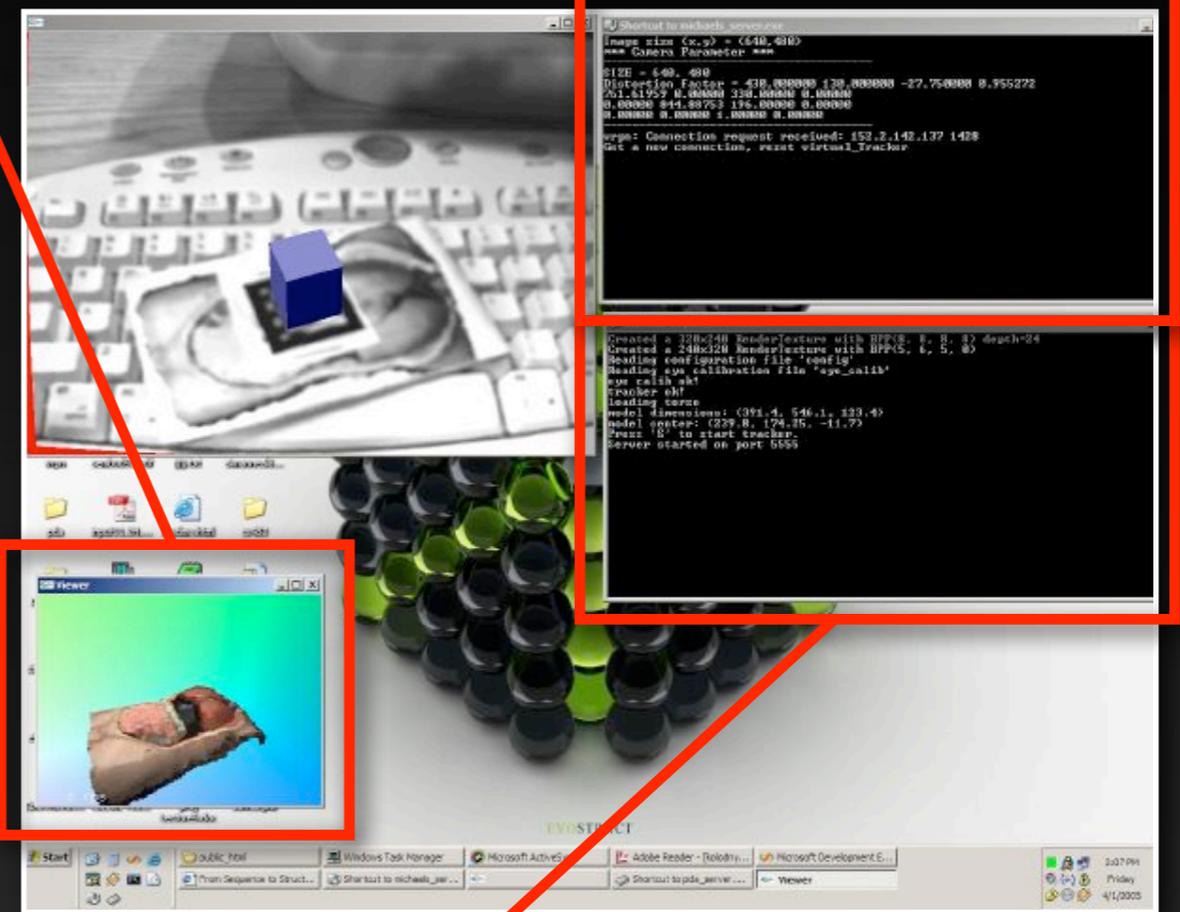
Vision-Based Prototype

ARToolkit



Reconstruction Server

Tracking Server



PDA Client

Tracking/Reconstruction Client
and PDA Server

Networking Research

Led by Prof. Ketan Mayer-Patel
UNC Chapel Hill



Networking Challenges

- Channel Management
 - Congestion control
 - Wireless vs. Wired
- Media Representations and Encoding
 - Interstream semantics and redundancy
 - Depth and sensor coding
- Adaptation
 - Policy specification and development
 - Real-time realization

Utility-based Adaptation

- Tunable
 - Can parameterize distance function with scaling coefficients
- Mechanical
 - Greedy algorithm maximizes utility / cost
 - Allows for real-time implementation
- Extensible
 - Data graph changes dynamically with available data sources
- Expressive
 - Euclidean distance is our first attempt, but more complex functions are possible

David Gotz and Ketan Mayer-Patel, *A general framework for multidimensional adaptation*, ACM Multimedia 2004

Recent Results

- Two new approaches to packet loss significantly improve system performance over existing techniques: Smart Reliability and Smart Encoding
- Smart Reliability edges out Smart Encoding in almost all cases but difference is small.
- Details in:
 - *A Utility-Driven Framework for Loss and Encoding Aware Adaptation*
 - Srinivas Krishnan and Ketan Mayer-Patel
 - To be presented at ACM SIGMM 2007
 - Ausberg, Germany, September 22-29, 2007

Evaluating the Potential of 3D Telepresence Technology In Emergency Healthcare

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Hanna M. Söderholm², Ph.D. Student

Bruce Cairns¹, M.D.

James E. Manning¹, M.D.

Eugene B. Freid^{1,3}, M.D.

Jim Mahaney¹, Technician

1. *The University of North Carolina at Chapel Hill*

2. *Göteborg University and The University College of Borås*

3. *The University of Florida*



Motivation

- Trauma
 - The “hidden epidemic of modern society”
 - Responsible for more productive years lost than heart disease, cancer & stroke combined
 - Complex, dynamic healthcare & work situation
- Could 3D telepresence technology improve emergency health care?
- \$\$\$ still needed to develop 3D technology

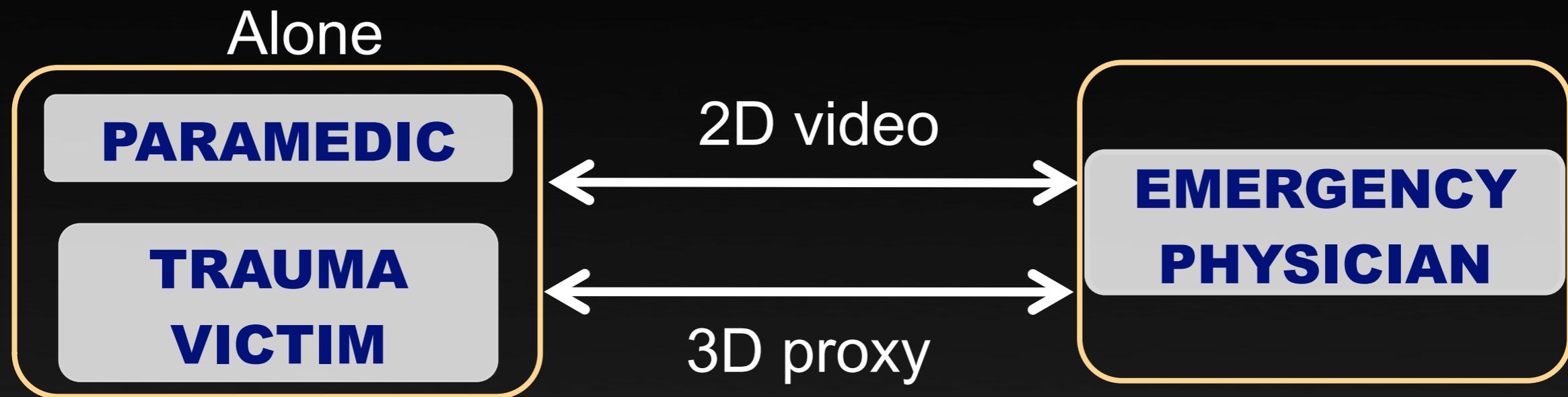
Need to evaluate the potential of the 3D technology
in the context of emergency medical care
before the technology exists

Evaluation Hypotheses

Comparison between conditions

	<u>Alone</u>	<u>2D video</u>	<u>3D proxy</u>
H1: Quality of medical care		<	<
H2: Paramedic self-efficacy		<	<
H3: Quality of interaction			<

Post-Test, Between-Subjects Experiment Design



- Trauma victim (patient)
 - METI human patient simulator
- Paramedics
 - 20 per condition, 60 total
 - Average 7 years of professional experience
- 2 Emergency physicians: Bruce Cairns & Jim Manning
 - Shared interaction style

Emergency Medical Task Scenario

- Management of the difficult airway
 - Diagnosis & perform a cricothyrotomy
- Most common cause of preventable death in prehospital care of injured patients
- Car accident scenario



Evaluation Measures & Data

- H1: Quality of medical care
 - Task execution times
 - Subtask performance
 - Occurrence of harmful interventions
 - Each session video-recorded
- H2: Paramedic self-efficacy
 - Post-questionnaire: basic airway management & cricothyrotomy tasks
- H3: Physician-paramedic interaction (paramedics' perspective)
 - Post-questionnaire: characteristics of interaction, usefulness of information
 - Post-interviews: open-ended questions regarding interaction



Ecology Validity[†]

Paramedic's perspective regarding how closely the simulation mirrors real world conditions

<u>Question*</u>	<u>Mean</u>	<u>SD</u>
The simulation was realistic	5.80	1.246
I was absorbed intensely in the activity	6.05	0.899
I concentrated fully on the activity	6.20	0.971

**Response scale: 1 (strongly disagree) to 7 (strongly agree)*

[†] *Ecological Validity* has typically been taken to refer to whether or not one can generalize from observed behavior in the laboratory to natural behavior in the world. (Schmuckler, 2001)

Harmful Interventions Performed

	Condition		
	<u>Alone</u>	<u>2D</u>	<u>3D Proxy</u>
Nasal intubation	1	1	0
Chest decompression	4	0	0
Not locating cricothyroid membrane	3	1	0
Improper incision	3	1	0
Airway tube slippage	0	4	1
Totals	11	7	1



Physician-Paramedic Interaction

Usefulness of Information

<i>How did the info you received from the M.D. contribute to:</i>	<u>2D Mean</u>	<u>3D Proxy Mean</u>	<u>ANOVA ρ</u>
Diagnosing the patient	5.68	6.41	.032
Intubating the patient	6.00	6.26	.620
Performing a cricothyrotomy	6.30	6.84	.013
Increasing your knowledge about treatment	5.89	6.84	.002
Enhancing your future performance	6.35	6.63	.002
Overall	6.05	6.63	.002

Physician-Paramedic Interaction

Challenges

- Twice as many paramedics reported challenges interacting with MD in 2D condition vs. 3D proxy condition
- 86% of the challenges reported for the 3D proxy condition focused on the initial awkwardness
- 2D participants also reported 4 additional problems
 - MD should have been more assertive in his communication
 - MD should have provided more feedback
 - MD did not always see what needed to be seen
 - They had to change their behavior to accommodate MD

*“I got frustrated with the video conferencing.
Felt a little like an idiot.”* 2D participant

Future Requirements

- Best practice procedures to reduce intimidating paramedic

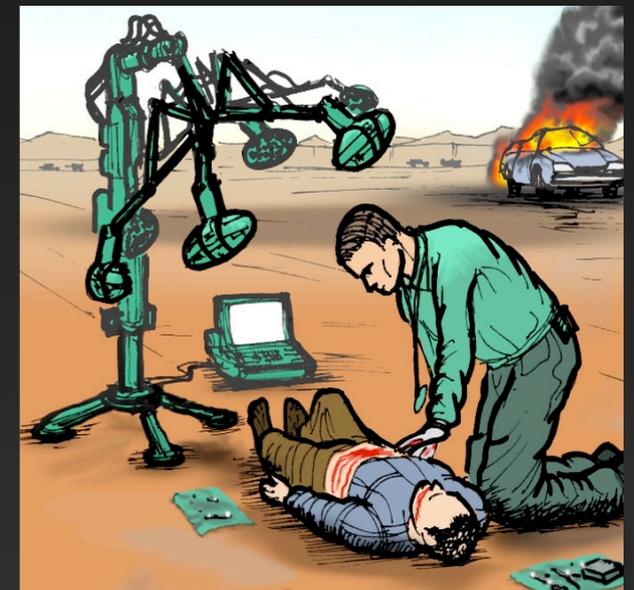
*“It was nice that [the M.D.] was there and he had your back
But then again it’s kind of intimidating because...you’re
scared you might mess up, and they say, we want you
trained better than this.”*

- Benefits to seeing M.D.

*“To see his face actually helped me with my confidence...
[helped] me focus on what I needed to focus on...
And just helped to calm me down.”*

- Ability of M.D. to point virtually in real time

*“I liked that he was able to point and tell me
what goes where and all.”*



Summary

Comparison between conditions

Alone

2D

3D proxy

H1: Quality of medical care

Partially supported

H2: Paramedic self-efficacy

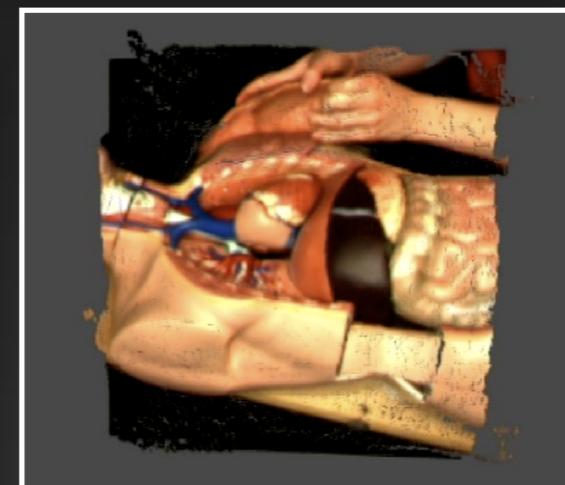
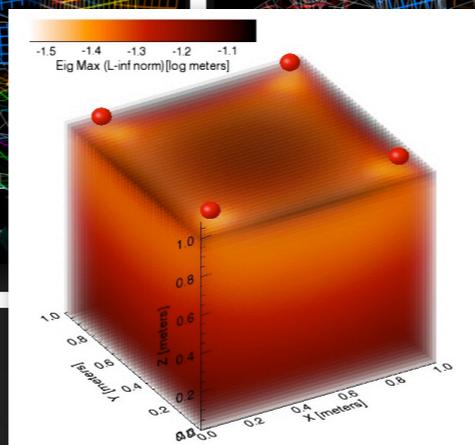
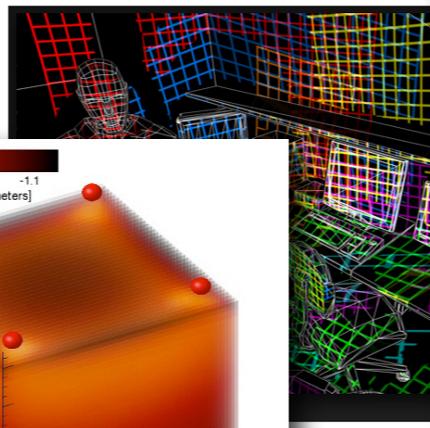
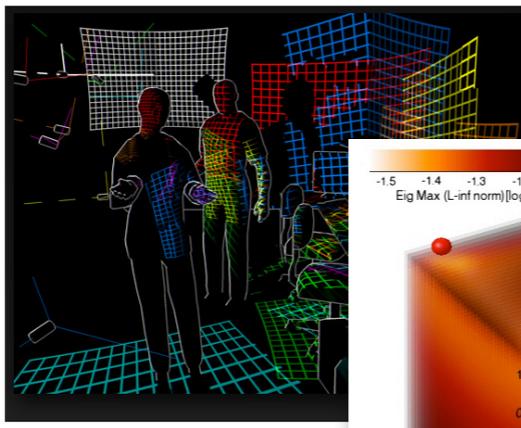
Supported

H3: Quality of interaction

Supported

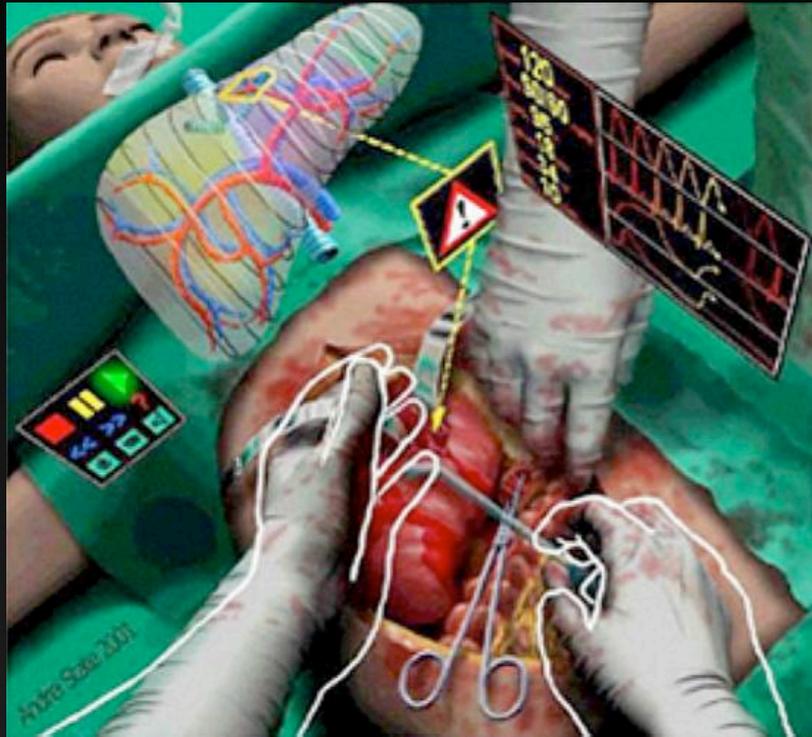


Summary: Hypothesize, Design, Simulate, Prototype, Evaluate



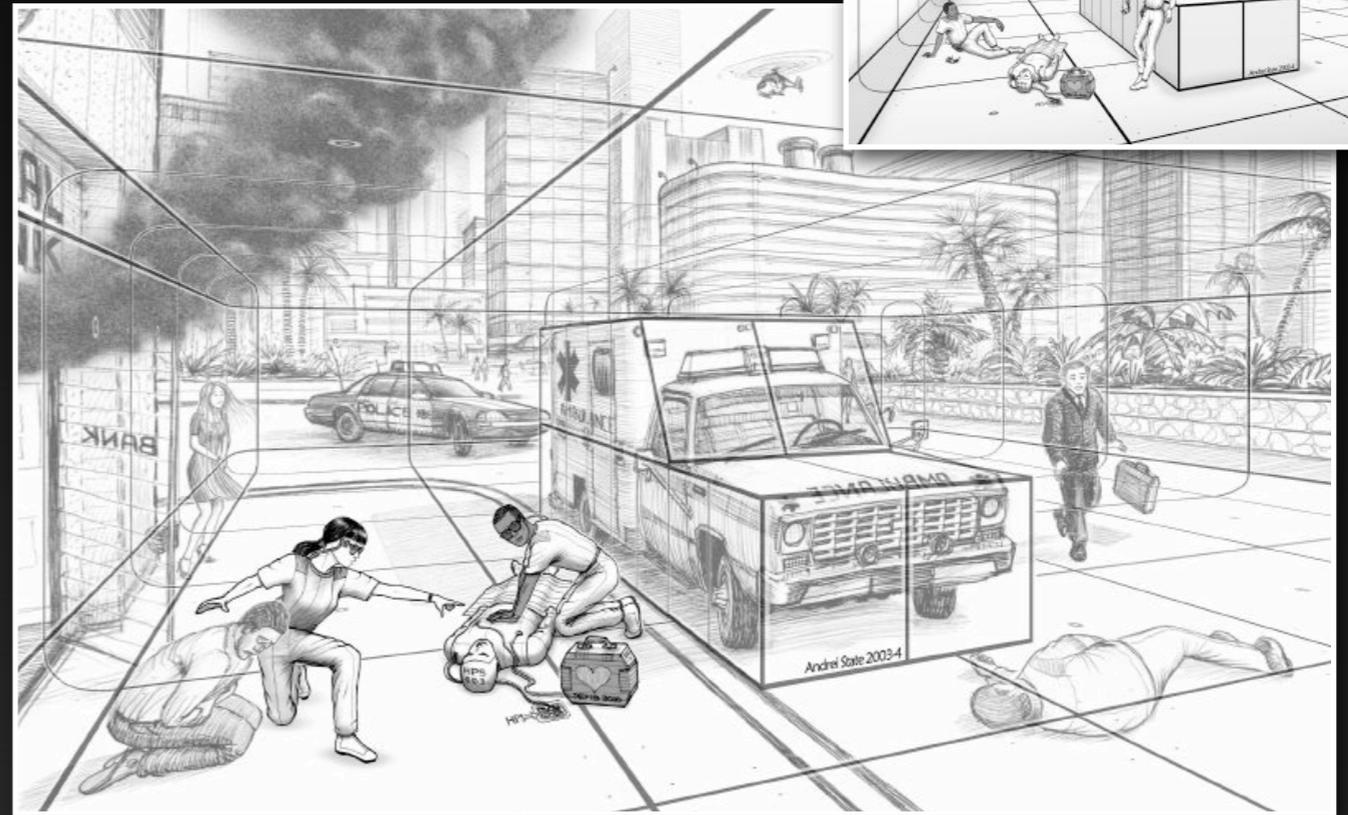
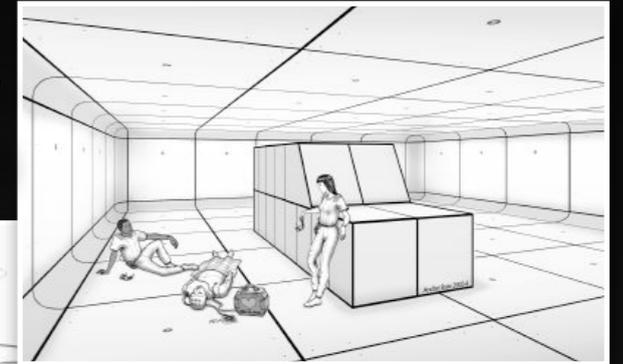
3D Telepresence Over Space, Time, and Imagination

See one, do one, teach one. (See more, more often, better.)



Andrei State, UNC, 2001

Brooks et al. (UNC), Cannon-Bowers et al. (UCF)



Andrei State, 2004

*I hear and I forget.
I see and I remember.
I do and I understand. —Confucius*

The End